U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-284 985

Heavy-Duty Fuel Economy Program Phase I. Specific Analysis of Certain Existing Data

Southwest Research Inst, San Antonio, Tex

Prepared for

Environmental Protection Agency, Ann Arbor, Mich Emission Control Technology Div

Jan 77

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-460/3-77-001

2.

3. RECIPIENT'S ACCESSION NO.
PB284985

4. TITLE AND SUBTITLE
Heavy-Duty Fuel Economy Program
Phase I, Specific Analysis of Certain Existing Data

5. REPORT DATE
January 1977

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Melvin N. Ingalls and Robert L. Mason

8. PERFORMING ORGANIZATION REPORT NO.
AR-11-4311

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78284

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
68-03-2220

12. SPONSORING AGENCY NAME AND ADDRESS
U.S. Environmental Protection Agency
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Ann Arbor, Michigan 48105

13. TYPE OF REPORT AND PERIOD COVERED
Phase I Final Report

14. SPONSORING AGENCY CODE
200/05

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report presents the results of several specific items of analysis conducted on heavy-duty vehicle data generated from two EPA projects. The purpose of the analysis was to provide information on the relationship between engine dynamometer fuel consumption and emissions and fuel consumption and emissions of trucks in actual use. Two separate tasks are covered. In the first task, ten specific items of analysis were performed on the gasoline-powered and diesel-powered truck fuel consumption and emissions data generated under EPA Contract 68-03-2147, "Study of Emissions from Heavy-Duty Vehicles". In the second task, the data from CRC Project CAPE-21-71, "Truck Driving Pattern and Use Survey" were utilized to attempt to develop modal coefficients for both the 9-mode heavy-duty gasoline and 13-mode heavy-duty diesel emissions tests that would correlate the 9 and 13-mode BSFC values with fuel economy of trucks in actual use. This latter attempt was largely unsuccessful.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Fuel Consumption Exhaust emissions Statistical analysis Trucks	Heavy-duty Vehicles 9-mode emission tests 13-mode emission tests	

18. DISTRIBUTION STATEMENT
Unlimited

19. SECURITY CLASS *(This Report)*
---

20. SECURITY CLASS *(This page)*
---

21. NO. OF PAGES
457

22. PRICE
PC A20/ MF A01

EPA Form 2220-1 (9-73)

PB 284 985

EPA-460/3-77-001
January 1977

HEAVY-DUTY FUEL ECONOMY PROGRAM - PHASE I, SPECIFIC ANALYSIS OF CERTAIN EXISTING DATA

Motor Vehicle Emission Lab
LIBRARY

REPRODUCED BY
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

457

EPA-460/3-77-001

HEAVY-DUTY FUEL ECONOMY PROGRAM - PHASE I, SPECIFIC ANALYSIS OF CERTAIN EXISTING DATA

by

Melvin N. Ingalls and Robert L. Mason, PhD

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78284

Contract No. 68-03-2220

EPA Project Officer: Andrew W. Kaupert

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

January 1977

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - in limited quantities - from the Library Services Office (MD-35), Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

This report was furnished to the Environmental Protection Agency by Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78284, in fulfillment of Contract No. 68-03-2220. The contents of this report are reproduced herein as received from Southwest Research Institute. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-460/3-77-001

FOREWORD

This project was conducted for the U.S. Environmental Protection Agency by the Department of Emissions Research of Southwest Research Institute. This phase of the project began in August 1975 and was completed in November 1976. The project was conducted under EPA Contract No. 68-03-2220 and was identified within Southwest Research Institute as Project 11-4311.

The EPA Project Officer for this project was Mr. Andrew Kaupert of the Emissions Control Technology Division, Office of Mobile Source Pollution Control, Environmental Protection Agency, Ann Arbor, Michigan. Mr. Karl J. Springer, Director of Department of Emissions Research at Southwest Research Institute, served as Project Manager. This phase of the project was under the supervision of Mr. Melvin N. Ingalls, Senior Research Engineer, as Project Leader. Dr. Robert L. Mason, Senior Research Statistician, performed most of the statistical analysis.

Project review meetings involving EPA and SwRI personnel, either at SwRI or the EPA facility in Ann Arbor, Michigan were held on July 15, 1975; August 4 and 5, 1975; October 15, 1975; January 6, 1976; April 13 and 14, 1976; May 25, 1976; and July 29, 1976.

ABSTRACT

This report presents the results of several specific items of analysis conducted on heavy-duty vehicle data generated from two EPA projects. The purpose of the analysis was to provide information on the relationship between engine dynamometer fuel consumption and emissions, and fuel consumption and emissions of trucks in actual use. Two separate tasks are covered. In the first task, ten specific items of analysis were performed on the gasoline-powered and diesel-powered truck fuel consumption and emissions data generated under EPA Contract 68-03-2147, "Study of Emissions from Heavy-Duty Vehicles." In the second task, the data from CRC Project CAPE-21-71, "Truck Driving Pattern and Use Survey," were utilized in an attempt to develop modal coefficients for both the 9-mode heavy-duty gasoline and 13-mode heavy-duty diesel emissions tests that would allow the 9 and 13-mode BSFC values to reliably predict fuel economy of trucks in actual use. This latter attempt was largely unsuccessful.

SUMMARY

This study was undertaken to assist EPA in addressing two basic issues. The first issue was whether a steady-state, heavy-duty emission test would reflect truck emission levels obtained during transient driving cycles. This would indicate that a steady-state certification test could be capable of predicting driving cycle emissions. If a steady-state test could predict driving cycle emissions, it is desirable to know if changes in heavy-duty emission control systems will alter or invalidate the relationship between the steady-state emissions and the driving cycle emissions.

The second item addressed was whether the brake specific fuel consumption (BSFC) obtained from the heavy-duty certification tests (gasoline and diesel) could be used to predict truck fuel economy in actual use. In addressing these two issues, two different sets of existing heavy-duty data were used. The findings are summarized separately in the following paragraphs.

1. Gasoline Truck Cycle Analysis

To investigate the relationship between steady-state emissions and transient driving cycle emissions, data from the 18 gasoline-powered trucks tested under EPA Contract 68-03-2147 were analyzed to answer 10 specific questions asked by EPA. In that project, fuel consumption and exhaust emissions data were obtained on heavy-duty trucks ranging from 7700 kg (17,000 lbs) to 18,370 (40,500 lbs) GVW on chassis dynamometers. A chassis version of the 9-mode FTP was conducted on all trucks. Eight different constant speed tests, three different sinusoidal cycles, and four different average speed transient driving cycles were run on each truck at three different inertia settings. The data used in this analysis were fuel rate, HC, CO, and NO_x emissions in grams/min. The results of the analysis are summarized below on an item-by-item basis.

Item 1 - How well does test-to-test variability of a cycle compare with cycle-to-cycle variability for cycles of the same average speed? For all cycles?

It was determined that test-to-test variability of the emission levels was significantly smaller than the cycle-to-cycle variability for different type chassis dynamometer cycles at the same average speed. Thus, emission and fuel rate differences between steady-state, sinusoidal and fully transient driving cycles could be evaluated.

Item 2 - How well can fuel consumption and emissions measured by the present 9-mode FTP predict the fuel consumption and emissions over other cycles?

For all three load levels both mode 1 (idle) and the composite 9-mode FTP are highly correlated with other operating conditions (steady state, sinusoidal and transient) in the production of HC. Also, for all load levels, modes 2, 4, 6, 8 (16" of mercury manifold vacuum) are highly correlated with other operating conditions in the production of CO and the use of fuel. However, in no case does an individual mode or the composite 9-mode value highly correlate with any other operating condition for all loads and all emissions. Using a technique known as quadratic programming, new weights for the composite 9-mode FTP were developed. Like the original 9-mode FTP, the weights for the new FTP are restricted to being positive and summing to one. However, some modes were assigned zero as a weighting factor. The effect of reweighting is to increase the correlations between the predicted and actual emissions for the sample of vehicles in the study.

Looking at only the 32 ± 8 and 48 ± 8 sinusoidal and the 16, 24, and 32 average kilometers per hour transient cycles, HC emissions predicted from the reweighted composite 9-mode FTP are highly correlated with actual HC emissions for each cycle-load combination. Predicted and actual NO_x emissions are highly correlated for each cycle-full load combination. NO_x emissions for other cycle-load combinations, and CO emissions and fuel consumption for all cycle-load combinations are less reliably predicted.

The weighting factors developed as part of the quadratic programming solution result in the highest correlation between predicted and actual emissions possible under the restrictions that a) each of the weighting factors is positive and b) they sum to one. By completely relaxing these restrictions and allowing the weighting factors to take on any value, the correlation between predicted and actual emissions can be increased. Ordinary least squares (OLS) is a technique which can be used to develop these unrestricted weights. A modification of the ordinary least squares technique known as stepwise OLS was used to determine the most important modes since the number of vehicles is only marginally greater than the number of modes and emissions from one mode are highly correlated with emissions from other modes. The stepwise OLS technique selects and weights those of the modes which best predict emissions. Not all modes are selected. It should be pointed out that for engineering reasons it is more desirable to have all modes included, because the fewer the modes, the easier it is to control emissions of those modes only, leaving the majority of the engine operation untouched. However, this method will identify those modes which best predict the emissions and fuel rate.

For all load levels, mode 1 (idle) and mode 9 (closed throttle) best predict HC emissions from the 32 ± 8 and 48 ± 8 sinusoidal and 8, 16, 24, and 32 average kilometer per hour transient driving cycles. Over the same cycles, mode 7 (3" mercury manifold vacuum) best predicts CO emissions under a full load condition. NO_x emissions are best predicted using modes 3 (10" mercury manifold vacuum) and 7 for all driving-load combinations. Finally, fuel consumption is best predicted using mode 5 (19" mercury manifold vacuum) for all driving-load combinations.

It is not recommended that the weighting factors produced here be considered for use as weighting factors for a certification test. One of the reasons for this recommendation is that a different set of weighting factors was produced for each emission, cycle type and vehicle load combination, giving 60 different sets of weighting factors. In alsmost every set, there was at least one mode where the weighting factor equalled zero. A second reason is that the relationships between the 9-mode emissions and driving cycle emissions are highly dependent on certain vehicle controlled parameters. When the physical reasons behind the correlations were examined, it was found that with the possible exception of HC, emissions and fuel rate from the transient driving cycles were strongly influenced by vehicle weight/engine power ratio. This parameter was not taken into account in the analysis of this question. Thus a different set of trucks would probably give a different set of weighting factors. Some of the correlations obtained may be useful in impact analysis, if the truck groups are similar to those tested here.

Item 3 - Will substituting a WOT mode for the 3" vacuum mode of the 9-mode cycle improve the correlation between the 9-mode cycle and other cycles?

It was determined that substituting a WOT mode for 3" vacuum mode of the 9-mode FTP would not improve the correlation between 9-mode emissions or fuel rate and other cycle emissions or fuel rate. Nor does substituting the WOT mode alleviate any of the other problems associated with correlating the 9-mode and driving cycle emissions listed under Item 2. This finding should not be taken to indicate that a WOT mode should not be part of any future heavy-duty gasoline certification test. From an engineering viewpoint, a WOT mode may be necessary to ascertain emissions levels with carburetor enrichment in operation.

Item 4 - How does the percent change in fuel rate and emissions for various levels of control measured over the 9-mode cycle compare with the change in fuel rate and emissions over other cycles?

Changes in 9-mode FTP fuel rate and emissions from precontrolled to 1970 and 1974 levels of control were found not to correlate with changes in dynamometer driving cycle fuel rate and emissions from precontrolled to 1970 and 1974 levels of control. This lack of ability to predict changes in chassis dynamometer transient driving cycle emissions from changes in 9-mode emissions reveals a second area of possible concern in the development of future steady-state engine dynamometer cycles.

Item 5 - How different are the rpm-time profiles and manifold vacuum-time profiles for a given transient cycle and load for different trucks?

The majority of the 18 gasoline-powered trucks tested did not have similar patterns of engine operation (rpm and manifold vacuum) for the same driving cycle. This finding also impacts on cycle development studies, since it indicates that one engine cycle (in terms of rpm and power) will not be equivalent to the same driving cycle for all trucks.

Item 6 - For an average speed of 32 kph, how well do sinusoidal fuel consumption and emissions approximate a fully-transient cycle fuel consumption and emissions? Above 32 kph, how well does a steady-state approximate a sinusoidal cycle ?

The relationships between steady-state test cycle and sinusoidal test cycle emissions and fuel rate and between sinusoidal cycle and completely transient test cycle emissions and fuel rate were determined. As would be expected, there is a decreasing correlation for all variables of any two cycles as the cycles become less alike. This implies that steady-state and sinusoidal test cycles should not be used to determine emissions from transient driving cycles.

Item 7 - Does load setting have the same effect on fuel rate and emissions for each average speed? Do fuel rate and emissions vary with average speed? Do fuel rate and emissions vary with different cycles at the same average speed?

In general, it was found that changes in vehicle load alone cannot account for changes in emissions or fuel rate for various test cycles at a constant speed and that speed does alter the effect of load on emissions and fuel rate. In general, at one load setting emissions and fuel rate do vary with speed. Speed seems to affect NO_x and fuel rate more than HC and CO. On a fleet average basis, except for NO_x at 8 kph and all emissions and fuel rate at 64 kph steady state and 64 kph ± 3 kph sinusoidal cycle emissions and fuel rate varied with different cycles at the same average speed. These results indicate that speed, load and cycle type must be considered together in any comparison of engine modal emissions with vehicle test cycle emissions.

Item 8 - How does the SARR data compare with other 32 kph transient driving cycles?

The average cumulative frequencies of vehicle speed and engine rpm from the 32 km/hr cycles were compared with the averages from the San Antonio Road Route studies. The cumulative frequencies of vehicle speed and engine rpm from the two projects were different. It is not known if these differences are due to differences in truck fleet composition or to actual differences in cycles. However, this analysis may indicate that average speed alone is not sufficient to describe a transient driving cycle. Both vehicle speed and engine rpm cumulative frequencies must also be defined.

Item 9 - Can fuel rate and emissions be highly correlated with percent time at idle?

The relationship between test cycle emissions (or fuel rate) and percent time spent at idle for the various test cycles was examined. While there is a negative trend of emissions and fuel rate with percent time at idle, it is not sufficient for predictive pruposes. Normalizing the variable improves the correlation as does using an exponential equation form for CO, NO_x and fuel rate. However, only for fuel rate was the improvement sufficient enough that it might be used for predictive purposes. This analysis indicates that emissions from a transient driving cycle cannot be predicted by comparing the percent time at idle with a driving cycle whose emissions are known.

Item 10 - Develop corrections to heavy duty emission factors for vehicle speed, vehicle weight, power/load ratio and mileage.

Regression equations were developed for the effects of speed, load, power/load ratio and mileage on emissions and fuel rate for heavy-duty gasoline trucks. Separate equations were developed for each level of emission control. In addition to the data from Contract 68-03-2147, data from the San Antonio Road Route studies (Contracts EHS 70-113 and 68-03-0441) were used in the analysis. The primary use for these regression equations is to provide the means to adjust published truck emission factors for speed, load, power/load ratio and mileage.

In summary, this analysis tends to indicate that the current 9-mode test (or variations of the 9-mode test) could not be expected to adequately predict emissions of gasoline powered trucks operating under actual driving condition. With additional work in this area, predictions adequate for ambient impact studies could possibly be developed. It was also found that the 9-mode procedure cannot adequately predict changes in emissions during actual driving cycles as the levels of emission control are changed.

2. Diesel Truck Cycle Analysis

To investigate the relationship between diesel steady-state and transient driving cycle emissions, emissions and fuel rate in g/min from the 12 diesel trucks tested under EPA Contract 68-03-2147 were analyzed for nine of the same ten items requested for the gasoline-powered trucks. In that contract, fuel rate and exhaust emissions were obtained on 12 diesel trucks ranging from 9070 kg (20,000 lbs) to 33,000 kg (73,000 lbs) GVW. A chassis version of the 13-mode FTP was conducted on all trucks. Eight different constant speed tests, three different sinusoidal tests, and four different average speed transient driving cycles were run on each truck at three different inertia settings. The results of the analysis of that data are summarized below on an item-by-item basis.

Item 1 - How well does test-to-test variability of a cycle compare with cycle-to-cycle variability for cycles of the same average speed? For all cycles?

It was determined that for all but a few of the test cycles, test-to-test variability of emission levels was significantly smaller than the cycle-to-cycle variability for different type chassis dynamometer cycles at the same average speed. Thus, emission and fuel rate differences between steady-state, sinusoidal, and fully transient driving cycles could be evaluated.

Item 2 - How well can fuel consumption and emissions measured by the present 13-mode FTP predict the fuel consumption and emissions over other cycles?

For the composite 13-mode emissions and fuel rate only HC and NO_x were highly correlated with any of the chassis dynamometer cycles. The individual modal HC and NO_x generally were highly correlated with some of the chassis dynamometer cycle HC and NO_x, while CO and fuel rate only rarely showed high correlations with the chassis dynamometer results. There is no one mode in which all the emissions and fuel rate are highly correlated with any of the test cycles.

It was found that, except for CO, there were positive linear relationships between the composite 13-mode emissions and fuel rate and the chassis dynamometer sinusoidal and transient driving cycle emissions and fuel rate for individual combinations of emission specie and test cycle. Using a technique known as quadratic programming, new weighting factors for the 13-mode test were developed. Like the FTP 13-mode weighting factors, the new factors were restricted to being positive and summing to one. However, some of the modes were assigned zero as a weighting factor. The correlations using these new weighting factors were always better, sometimes greatly better than the original correlations. The reweighted composite 13-mode NO_x emissions were highly correlated with the transient driving cycle emissions. While there is a different set of NO_x weighting factors for each vehicle load and test cycle combination, the NO_x correlations are high enough to be useful in predicting driving cycle NO_x for the diesel engine mix used in this study. The reweighting was also done using all emission species and fuel rate as if they were one variable, producing one set of weighting factors for each test cycle and test weight combination. The correlations from these weighting factors were not as good as those using the various emissions individually.

A stepwise regression was also performed to determine what the weighting factors would be if unconstrained and to identify those modes which best predict the emissions and fuel rate. The mode that entered the equation first was the one that best correlated with test cycle results. For each emission type, there was one mode which generally, though not always, entered first. For HC, emissions mode 2 (intermediate speed, 2 percent power) generally entered first. For CO emissions, modes 8 (rated speed, 100 percent power) and 10 (rated speed, 50 percent power) were entered first most often. For NO_x, mode 2 was entered first for the empty load tests; while mode 5 (intermediate speed, 75 percent power) was generally entered first for the half and full load tests. For fuel rate, only for the empty load tests was there one mode, idle, that was generally entered first.

It is not recommended that the weighting factors produced by this analysis be considered for use as weighting factors for a certification test. One of the reasons for this recommendation is that a different set of weighting factors was produced for each emission, cycle type and vehicle load combination, giving a total of 60 different sets of weighting factors. In almost every set there was at least one mode where the weighting factor equalled zero. A second reason is that the relationships between the 13-mode emissions and driving cycle emissions are highly dependent on certain vehicle controlled parameters. Fuel rate and probably emissions were found to be strongly influenced by vehicle weight/engine power ratio. This parameter was not taken into account in the analysis of this question. Thus, a different set of trucks would probably give a different set of weighting factors.

Item 3 - Item 3 applied to the gasoline powered trucks, but not to the diesel powered trucks. It is mentioned here merely to keep the item numbers consistent between the gasoline and diesel truck analyses.

Item 4 - How does the percent change in fuel rate and emissions for various levels of control measured over the 13-mode cycle compare with the change in fuel rate and emissions over other cycles?

In general, changes in 13-mode FTP fuel rate and emissions from precontrolled to 1974 level of control were found not to correlate well with changes in driving cycle fuel rate and emissions from precontrolled to 1974 levels of control. The exceptions to this were NO_x and fuel rate for certain cycles. This lack of ability to predict changes in transient driving cycle emissions from changes in 13-mode emissions reveals a second area of possible concern in the development of future steady-state engine dynamometer cycles.

Item 5 - How different are the rpm-time profiles and percent power-time profiles for a given transient cycle and load for different trucks?

The majority of the 12 diesel trucks tested did not have similar patterns of operation (rpm and percent power) for the same driving cycle. This finding also impacts on cycle development studies, since it indicates that one engine cycle (in terms of rpm and power) will not be equivalent to the same driving cycle for all trucks.

Item 6 - For an average speed of 32 kph, how well do sinusoidal fuel consumption and emissions approximate a fully-transient cycle fuel consumption and emissions? Above 32 kph, how well does a steady-state approximate sinusoidal cycle?

The relationship between steady-state test cycle and sinusoidal test cycle emissions and fuel rate and between sinusoidal cycle and completely transient test cycle emissions and fuel rate were determined. Except for fuel rate, there is a decreasing correlation for all variables of any two cycles as the cycles become less alike. Only for NO_x emissions are the correlations high enough that a transient driving cycle could be predicted adequately from a sinusoidal cycle or a sinusoidal cycle be predicted from a steady state cycle. This analysis indicates that, except for NO_x, steady state and sinusoidal test cycles should not be used to determine emissions from transient driving cycles.

Item 7 - Does load setting have the same effect on fuel rate and emissions for each average speed? Do fuel rate and emissions vary with average speed? Do fuel rate and emissions vary with different cycles at the same average speed?

The effect of vehicle weight on fuel rate and emissions for each average speed was investigated. Load setting alone was generally not statistically significant in its influence on emissions and fuel consumption. For HC, load setting did have a different effect on emissions for different speeds; but only occasionally did the relationship of HC emissions with load change significantly with speed. Except for the sinusoidal test cycles, load did not have the same effect on CO, NO_x and fuel rate for each average speed. Fuel rate and emissions also varied with average speed at the same load setting. However, whether speed had a statistically significant influence on fuel consumption and emissions was dependent on the type of test cycle and emission type. Based on averages for all trucks, the fuel rate and emissions differed with different cycles at the same average speed for about half the time. However, individual trucks varied greatly from the average pattern. These results indicate that speed, load and cycle type must be considered together in any comparison of engine modal emissions with vehicle test cycle emissions.

Item 8 - How does the SARR data compare with other 32 kph transient driving cycles?

The average cumulative frequencies of vehicle speed and engine rpm from the 32km/hr cycles were compared with the averages from the San Antonio Road Route studies. The three dynamometer driving cycle speed distributions were all fairly similar to each other between 20 and 65 kph. However, they differed from one another at the high and low speed ends. The average SARR vehicle speed distribution was different from the three dynamometer cycles. The rpm distributions of the two studies were shown to be statistically different. It is not known if these differences are due to differences in truck fleet composition. However, this analysis may indicate that average speed alone is not sufficient to describe a transient driving cycle. Both vehicle speed and engine rpm cumulative frequencies must also be defined.

Item 9 - Can fuel rate and emissions be highly correlated with percent time at idle?

The relationships between test cycle emissions (or fuel rate) and percent time spent at idle for the various test cycles were examined. Fuel rate can be highly correlated with percent time at idle for all trucks using logarithmic equations with a common slope but different intercepts. The HC emissions can be highly correlated to percent time at idle but only if a different equation is used for each truck. How well CO and NO_x can be correlated to percent time at idle differs from truck to truck. This analysis indicates that no one equation can be used to predict HC, CO or NO_x driving cycle emissions from percent time at idle. While fuel rate can be predicted from percent time at idle, it is not known if this relationship will change with different cycles and different fleet compositions.

Item 10 - Develop corrections to heavy duty emission factors for vehicle speed, vehicle weight, power/load ratio and mileage.

Regression equations were developed for the effects of speed, load, power/load ratio and mileage on emissionsand fuel rate for heavy-duty diesel trucks. Separate equations were developed for each level of emission control. In addition to the data from contract 68-03-2147, data from the San Antonio Road Route studies (Contract 68-01-2113) were used in the analysis. The primary use for these regression equations is to provide the means to adjust published truck emission factors for speed, load power/load ratio and mileage.

In summary, this analysis of diesel emissions data tends generally to indicate the current 13-mode test could not be expected to adequately predict emissions of diesel powered trucks operating under actual driving conditions. However, the 13-mode NO_x emissions developed here may be useful in predicting in-service diesel truck emissions for ambient air impact studies if the truck groups are similar to those tested here. With additional work in this area, relationships adequate for ambient air impact studies could possibly be developed for HC and CO. It was also found that the modal procedure could adequately predict changes only in NO_x and fuel rate for some cycles as levels of emission control are changed.

3. Gasoline Weighting Factor Development

This study did not result in a simple set of weighting factors that would relate the 9-mode BSFC to on-the-road fuel economy. It did show that there was no simple correlation between the 9-mode BSFC and vehicle fuel economy since variables such as vehicle weight and power/weight ratio must be considered. A rather cumbersome and empirical method that could predict vehicle fuel economy was explored. While considerable engine testing would be required to develop the method, it may warrant further consideration.

4. Diesel Weighting Factor Development

As was the case with the gasoline weighting factor development, this study did not result in a simple set of weighting factors that would relate the 13-mode composite BSFC to on-the-road fuel economy. The study did show that there was no simple correlation between the 13-mode composite BSFC and the vehicle fuel economy since the additional variables of vehicles weight/engine power ratio and engine rated power also affect vehicle fuel economy. An empirical method that could predict vehicle fuel economy was explored. While considerable engine and vehicle testing would be required to develop the method, it may warrant further consideration. However, considering the small differences in BSFC for diesel engines currently in use, it appears that proper engine to vehicle matching is more important than differences in BSFC in obtaining the best possible fuel economy.

TABLE OF CONTENTS

Page

FOREWORD iii

ABSTRACT iv

SUMMARY v

LIST OF FIGURES xvii

LIST OF TABLES xxi

I. INTRODUCTION 1

- A. Objectives 1
- B. Report Organization 1

II. DATA BASES AND STATISTICAL METHODS 2

- A. Data Bases
- B. Statistical Methods 4

III. GASOLINE TRUCK CYCLE ANALYSIS 5

Item 1 - How well does test-to-test variability of a cycle compare with cycle-to-cycle variability for cycles of the same average speed? For all cycles? 5

Item 2 - How well can fuel consumption and emissions measured by the present 9-mode FTP predict the fuel consumption and emissions over other cycles? 6

Item 3 - Will substituting a WOT mode for the 3" vacuum mode of the 9-mode cycle improve the correlation between the 9-mode cycle and other cycles? 26

Item 4 - How does the percent change in fuel rate and emissions for various levels of control measured over the 9-mode cycle compare with the change in fuel rate and emissions over other cycles? 31

Item 5 - How different are the rpm-time profiles and percent power-time profiles for a given transient cycle and load for different trucks? 37

TABLE OF CONTENTS (cont'd)

Page

Item 6 - For an average speed of 32 kph, how well do sinusoidal fuel consumption and emissions approximate a fully-transient cycle fuel consumption and emissions? Above 32 kph, how well does a steady-state approximate a sinusoidal cycle? 42

Item 7 - Does load setting have the same effect on fuel rate and emissions for each average speed? Do fuel rate and emissions vary with average speed? Do fuel rate and emissions vary with different cycles at the same average speed? 42

Item 8 - How does the SARR data compare with other 32 kph transient driving cycles? 52

Item 9 - Can fuel rate and emissions be highly correlated with percent time at idle? 57

Item 10 - Heavy-Duty Emissions Factor Analysis 67

IV. DIESEL TRUCK CYCLE ANALYSIS 88

Item 1 - How well does test-to-test variability of a cycle compare with cycle-to-cycle variability for cycles of the same average speed? For all cycles? 88

Item 2 - How well can fuel consumption and emissions measured by the present 13-mode FTP predict the fuel consumption and emissions over other cycles? 89

Item 3 - Item 3 applied to the gasoline-powered trucks but not to the diesel-powered trucks. 106

Item 4 - How does the percent change in fuel rate and emissions for various levels of control measured over the 13-mode cycle compare with the change in fuel rate and emissions over other cycles? 106

Item 5 - How different are the rpm-time profiles and manifold vacuum-time profiles for a given transient cycle and load for different trucks? 106

TABLE OF CONTENTS (cont'd)

Page

Item 6 - For an average speed of 32 kph, how well do sinusoidal fuel consumption and emissions approximate a fully-transient cycle fuel consumption and emissions? Above 32 kph, how well does a steady-state approximate a sinusoidal cycle? 114

Item 7 - Does load setting have the same effect on fuel rate and emissions for each average speed? Do fuel rate and emissions vary with average speed? Do fuel rate and emissions vary with different cycles at the same average speed? 114

Item 8 - How does the SARR data compare with other 32 kph transient driving cycles? 118

Item 9 - Can fuel rate and emissions be highly correlated with percent time at idle? 123

Item 10 130

V. GASOLINE WEIGHTING FACTOR DEVELOPMENT 150

VI. DIESEL WEIGHTING FACTOR DEVELOPMENT 186

LIST OF REFERENCES 216

APPENDICES

A. Description of Vehicles Tested and Listing of Special Computer Programs

B. Data in Support of Gasoline Truck Data Analysis

C. Data in Support of Diesel Truck Data Analysis

D. Data in Support of Gasoline Truck Weighting Factor Analysis

E. Data in Support of Diesel Truck Weighting Factor Analysis

F. Working Curves from EPA Analysis of Ethyl Truck and Bus Study

LIST OF FIGURES

Figure		Page
1	32 kph Driving Cycle Fuel Rate vs 9-Mode Fuel Rate for 9 Single Axle Trucks	19
2	Modal Fuel Rate vs Engine Displacement for 18 Gasoline-Powered Trucks	20
3	32 kph Driving Cycle Fuel Rate vs Vehicle Test Weight for 9 Single Axle Trucks	22
4	32 kph Driving Cycle Fuel Rate at Zero Slope Point vs Engine Size for 9 Single Axle Trucks	23
5	32 kph Driving Cycle Fuel Rate vs 9-Mode Fuel Rate for 9 Single Axle Trucks	25
6	Transient 32 kph HC and CO Emissions as a Function of 32 kph Sinusoidal HC and CO Emissions	44
7	Transient 32 kph NO_x Emissions and Fuel Rate as a Function of 32 kph Sinusoidal NO_x Emissions and Fuel Rate	45
8	Sinusoidal 48 kph HC and CO Emissions as a Function of 48 kph Steady-State HC and CO Emissions	46
9	Sinusoidal 48 kph NO_x Emissions and Fuel Rate as a Function of 48 kph Steady-State NO_x Emissions and Fuel Rate	47
10	Sinusoidal 64 kph HC and CO Emissions as a Function of 64 kph Steady-State HC and CO Emissions	48
11	Sinusoidal 64 kph NO_x Emissions and Fuel Rate as a Function of 64 kph Steady-State NO_x Emissions and Fuel Rate	49
12	Cumulative Percent Time Versus Vehicle Speed for the San Antonio Road Route and Three 20 mph Driving Cycles from Contract 68-03-2147	59
13	Cumulative Percent Time Versus Engine Speed for Gasoline-Powered Trucks Tested on CAPE-21, San Antonio Road Route, and 20 mph Driving Cycles from Contract 68-03-2147	61
14	HC Emissions as a Function of Percent Time at Idle for Nine Gasoline-Powered Trucks	63

LIST OF FIGURES (cont'd)

Figure		Page
15	CO Emissions as a Function of Percent Time at Idle for Nine Gasoline-Powered Trucks	64
16	NO_x Emissions as a Function of Percent Time at Idle for Nine Gasoline-Powered Trucks	65
17	Fuel Consumption as a Function of Percent Time at Idle for Nine Gasoline-Powered Trucks	66
18	Normalized CO as a Function of Percent Time at Idle	68
19	Normalized Fuel Consumption as a Function of Percent Time at Idle	68
20	NO_x Emissions from Two Half Load Transient Cycles as Functions of 13-Mode NO_x Emissions in grams per Minute	98
21	Comparison of Percent Change in Driving Cycle NO_x Emissions with Percent Change in 13-Mode NO_x Emissions	109
22	Comparison of Percent Change in Driving Cycle Fuel Consumption with 13-Mode Percent Change	110
23	Cumulative Percent Time Versus Vehicle Speed for Two Diesel Truck Studies	125
24	Cumulative Percent Time Versus Engine rpm for Two Diesel Truck Studies	127
25	Average Time Spent in Various Engine rpm Manifold Vacuum Conditions for All 35 Gasoline Trucks in New York CAPE-21 Study	159
26	Average Time Spent in Various Engine rpm Manifold Vacuum Conditions for All 26 Gasoline Trucks in Los Angeles CAPE-21 Study	160
27	Manifold Vacuum - Engine rpm Matrix Showing Engine Operating Areas in Terms of Throttle Position	161
28	Fuel Consumption Versus Engine Speed at 3" Intake Manifold Vacuum for Four Engines	163
29	Fuel Consumption Versus Engine Speed at 10" Intake Manifold Vacuum for Four Engines	164

LIST OF FIGURES (cont'd)

Figure		Page
30	Fuel Consumption Versus Engine at 16" Intake Manifold Vacuum for Four Engines	165
31	Fuel Consumption Versus Engine at 19" Intake Manifold Vacuum for Four Engines	165
32	Test Weight vs LA-4 Fuel Economy for 6 Trucks Tested under Contract 68-01-0472	171
33	Nine-Mode BSFC vs LA-4 Fuel Economy for 6 Trucks Tested under Contract 68-01-0472	171
34	Normalized Fuel Rate as a Function of Manifold Vacuum Average of 4 Engines	172
35	LA-4 Miles/Gallon as a Function of 9-Mode BSFC with Weighting Factors from CAPE-21 Percent Fuel Used	176
36	LA-4 Fuel Rate Normalized to 16,000 lb vs Optimized 9-Mode Fuel Rate Normalized to 400 CID for 6 Trucks Tested under Contract 68-01-0472	178
37	20 mph Driving Cycle Normalized Fuel Rate Versus Vehicle Weight for Several Trucks Tested under Contract No. 68-03-2147	179
38	Engine CID vs LA-4 Fuel Rate at Certain Vehicle Weights for 6 Trucks Tested under Contract 68-01-0472	180
39	Percent Difference from Fuel Rate Regression Line vs 9-Mode BSFC for 6 Trucks from Contract 68-01-0472	182
40	Engine CID vs LA-4 Fuel Rate at Certain Vehicle Weights	183
41	Average Time Spent in Various Percent Engine Speeds and Percent Power for All 17 Diesel Trucks in the Los Angeles CAPE-21 Study	195
42	Average Time Spent in Various Percent Engine Speeds and Percent Power for All 14 Diesel Trucks in the New York CAPE-21 Study	196
43	Diesel Truck Percent Power-Percent Speed Matrix Showing Engine Operating Areas	197

LIST OF FIGURES (cont'd)

Figure		Page
44	32 kph Driving Cycle Fuel Rate as a Function of Vehicle Test Weight for Seven Nonturbocharged Diesel Trucks	203
45	32 kph Fuel Rate as a Function of 13-Mode Composite BSFC for Six Nonturbocharged Diesel Trucks	204
46	32 kph Driving Cycle Fuel Rate as a Function of Weight/Power Ratio for Seven Nonturbocharged Diesel Trucks	207
47	32 kph Driving Cycle Fuel Rate at Constant Weight/Power Ratio as a Function of Engine Rated Power	208
48	Composite 13-mode Fuel Rate as a Function of Engine Rated Speed for Eight Nonturbocharged Diesel Engines	209
49	32 kph Driving Cycle Fuel Rate at Constant Weight/Power Ratio Versus Composite 13-Mode Fuel Rate Using CAPE-21 Weighting Factors	211
50	32 kph Driving Cycle Fuel Rate at Constant Weight/Power Ratio Versus Composite 13-Mode Fuel Rate Using FTP Weighting Factor	212
51	32 kph Driving Cycle Fuel Rate at Constant Weight/Power Ratio Versus Composite 13-Mode Fuel Rate Using Optimized Weighting Factors	213

LIST OF TABLES

Table		Page
1	Relationships Between Modal and Chassis Dynamometer Cycle Emissions Having Correlation Coefficients above 0.9 for Empty Load Tests (All Variables in Terms of grams/minute), Sample Size: Nine Single Axle Gasoline Trucks	8
2	Relationships Between Modal and Chassis Dynamometer Cycle Emissions Having Correlation Coefficients above 0.9 for Half Load Tests (All Variables in Terms of grams/minute), Sample Size: Nine Single Axle Gasoline Trucks	9
3	Relationships Between Modal and Chassis Dynamometer Cycle Emissions Having Correlation Coefficients above 0.9 for Full Load Tests (All Variables in Terms of grams/minute), Sample Size: Nine Single Axle Gasoline Trucks	10
4	Correlation Coefficients Between FTP Results and Driving Cycle Results for Nine Single Axle Gasline Trucks	11
5	Correlation Coefficients Between the Modes of the 9-Mode Gasoline Heavy-Duty FTP	12
6	Order of Entry in Stepwise Multiple Regression for Individual Modes of the Gasoline Heavy-Duty 9-Mode FTP for Nine Gasoline Trucks	14
7	Correlation Coefficients from Regression Analysis Between Reweighted 9-Mode Results and Driving Cycle Results for Nine Single Axle Trucks	16
8	Regression Equations Relating Reweighted Composite 9-Mode Emissions and Fuel Rate to Various Driving Cycle Emissions and Fuel Rate for Nine Single Axle Gasoline Trucks	17
9	Results of Special REgression Analysis to Optimize Correlation Between 9-Mode Fuel Rate and 20 mph Driving Cycle Fuel Rate for Nine Single Axle Trucks	24
10	Comparison of 9-Mode Composite Results for Regular 9-Mode FTP and a 9-Mode Test Including Wide Open Throttle	27
11	Relationships Between Modal and Chassis Dynamometer Cycle Emissions Having Correlation Coefficients above 0.9 for 9-Mode FTP Composite Results with WOT Replacing 3" Mode	28

LIST OF TABLES (cont'd)

Table		Page
12	Correlation Coefficients Between Results from WOT 9-Mode Tests and Driving Cycle Results for Nine Single Axle Trucks	29
13	Correlation Coefficients Between Reweighted WOT 9-Mode Tests and Driving Cycle Results for Nine Single Axle Trucks	30
14	Correlation Coefficients Between Driving Cycle Emissions and 9-Mode Emissions for Several Versions of the 9-Mode Test Cycle	32
15	Average Percent Change in Hydrocarbons for Various Levels of Emission Control (Pre-1970 Base Level)	33
16	Average Percent of Change in Carbon Monoxide for Various Levels of Emission Control (Pre-1970 Base Level)	34
17	Average Percent Change in Oxides of Nitrogen for Various Levels of Emission Control (Pre-1970 Base Level)	35
18	Average Percent Change in Fuel Rate for Various Levels of Emission Control (Pre-1970 Base Level)	36
19	Relationship Between Change in 9-Mode Composite Emissions and Change in Driving Cycle Emissions for 1970 to 1973 Level of Emission Control (Average Pre-1970 Base Level)	38
20	Relationship Between Change in 9-Mode Composite Emissions and Change in Driving Cycle Emissions for 1974 Level of Emission Control (Average Pre-1970 Base Level)	39
21	Gasoline-Powered Truck Pairs Showing Similar Manfold Vacuum and Engine rpm Distributions Using Kolmogorov-Smirnov Test	41
22	Linear Regression Equations and Correlation Coefficients of Fuel Consumption and Emissions for Various Driving Schedules	43
23	Comparison of Gasoline Truck HC Emissions in grams/minute from Different Driving Cycles at the Same Average Speed (Half Load Data)	53

LIST OF TABLES (cont'd)

Table		Page
24	Comparison of Gasoline Truck CO Emissions in grams/minute from Different Driving Cycles at the Same Average Speed (Half Load Data)	54
25	Comparison of Gasoline Truck NO_x Emissions in grams/minute from Different Driving Cycles at the Same Average Speed (Half Load Data)	55
26	Comparison of Gasoline Truck Fuel Rate in grams/minute from Different Driving Cycles at the Same Average Speed (Half Load Data)	56
27	Percent Time and Cumulative Percent Time Spent in Vehicle Speed Intervals from the 32 kph Transient Driving Cycles of Contract 68-03-2147 and from San Antonio Road Route Studies	58
28	Comparison of Time Spent in Various rpm Intervals for Several Gasoline-Powered Truck Studies	60
29	Percent Time in Idle Mode for Various Driving Cycles	62
30	Exponential Curve Fit Results for CO and NO_x Emissions and Fuel Consumption as a Function of Driving Cycle Percent Time at Idle	62
31	Averages of Some Important Variables from Several Heavy-Duty Gasoline Truck Studies	70
32	Results of Regression Analysis of Emissions and Fuel Consumption as a Function of Weight/CID for Various Gasoline Truck Groups	71
33	Average Emissions and Fuel Consumption for Several Heavy-Duty Truck Groups	73
34	Results of Regression Analysis for HC Emissions as a Function of Vehicle Speed for Various Engine Groups from Contract 68-03-2147	75
35	Results of Regression Analysis for CO Emissions as a Function of Vehicle Speed for Various Engine Groups from Contract 68-03-2147	76
36	Results of Regression Analysis for NO_x Emissions as a Function of Vehicle Speed for Various Engine Groups from Contract 68-03-2147	77

LIST OF TABLES (cont'd)

Table		Page
37	Results of Regression Analysis for Fuel Consumption as a Function of Vehicle Speed for Various Engine Groups from Contract 68-03-2147	78
38	Results of Regression Analysis for HC Emissions as a Logarithmic Function of Speed for Various Truck Groups from Contract 68-03-2147	79
39	Results of Regression Analysis for CO Emissions as a Logarithmic Function of Speed for Various Truck Groups from Contract 68-03-2147	80
40	Results of Regression Analysis for NO_x Emissions as a Logarithmic Function of Speed for Various Truck Groups from Contract 68-03-2147	81
41	Results of Regression Analysis for Fuel Consumption as a Logarithmic Function of Speed for Various Truck Groups from Contract 68-03-2147	82
42	Average Emissions from the 20 mph Transient Cycle for Gasoline Trucks Tested under Contract 68-03-2147	83
43	Results of Regression Analysis for Emissions and Fuel Consumption as a Function of Mileage and Weight/CID for Various Truck Groups	85
44	Results of Regression Analysis for Emissions and Fuel Consumption as a Function of Weight and Weight/CID for Various Truck Groups	86
45	Average Test Weights for Various Gasoline Truck Groups from Contract 68-03-2147	87
46	Diesel Truck Variables Having Correlation Coefficients Greater than 0.9 for Empty Load Tests	91
47	Diesel Truck Relationships Between Modal and Chassis Dynamometer Cycle Emissions Having Correlation Coefficients Greater than 0.9 for Half Load Tests, Sample Size: 12 Diesel Trucks	93
48	Diesel Truck Relationships Between Modal and Chassis Dynamometer Cycle Emissions Having Correlation Coefficients Greater than 0.9 for Full Load Tests, Sample Size: 12 Diesel Trucks	95

LIST OF TABLES (cont'd)

Table		Page
49	Correlation Coefficients from Between 13-Mode FTP Results and Dynamometer Test Cycle Results for 12 Diesel Trucks	97
50	Correlation Coefficients Between Modes of the 13-Mode Diesel Heavy-Duty FTP	100
51	Order of Entry in Stepwise Multiple Regression of Individual Modes of the Diesel Heavy-Duty 13-Mode FTP for 12 Diesel Trucks	101
52	Correlation Coefficients from Regression Analysis Between Reweighted 13-Mode Results and Driving Cycle Results for 12 Diesel Trucks	104
53	Average Percent Change in Diesel Emissions and Fuel Consumption Between Pre-1974 and 1974 and Later Diesel Trucks	107
54	Relationship of Change in 13-Mode Composite Results to Change in Driving Cycle Results for 1974 and Later Diesel Trucks (Average Pre-1974 Base Level)	108
55	Diesel Truck Pairs Showing Similar Percent Power and Engine rpm Distributions Using the Kolmogorov-Smirnov Test	112
56	Diesel Truck Pairs with Similar Percent Time in Various Power and rpm Intervals	113
57	Results of Regression Analysis on Emissions and Truck Rate for Several Chassis Dynamometer Test Cycles	115
58	Comparison of Diesel Truck HC Emissions in grams/minute from Different Driving Cycles with the Same Average Speed (Half Load Data)	119
59	Comparison of Diesel Truck CO Emissions in grams/minute from Different Driving Cycles with the Same Average Speed (Half Load Data)	120
60	Comparison of Diesel Truck NO_x Emissions in grams/minute from Different Driving Cycles with the Same Average Speed (Half Load Data)	121

LIST OF TABLES (cont'd)

Page		Page
61	Comparison of Diesel Truck Fuel Consumption in grams/minute from Different Driving Cycles with the Same Average Speed (Half Load Data)	122
62	Percent Time and Cumulative Percent Time Spent in Various Speed Intervals for the 32 kph Diesel Transient Cycles under Contract 68-03-2147 and the San Antonio Road Route Studies	124
63	Comparison of Time Spent in Various rpm Intervals for Two Diesel Truck Studies	126
64	Percent Time at Idle for Various Diesel Dynamometer Test Cycles	128
65	Regression Results for Emissions and Fuel Rate as a Function of Percent Time at Idle	129
66	Averages of Some Important Variables from Two Diesel Truck Studies	131
67	Results of Regression Analysis of Emissions and Fuel Rate as a Function of Weight/CID for Various Diesel Truck Groups	132
68	Average Emissions and Fuel Consumption for Two Diesel Truck Studies	134
69	Results of Regression Analysis for HC Emissions as a Function of Vehicle Speed for Various Diesel Truck Groups from Contract 68-03-2147	136
70	Results of Regression Analysis for CO Emissions as a Function of Vehicle Speed for Various Diesel Truck Groups from Contract 68-03-2147	137
71	Results of Regression Analysis for NO_x Emissions as a Function of Vehicle Speed for Various Diesel Truck Groups from Contract 68-03-2147	138
72	Results of Regression Analysis for Fuel Consumption as a Function of Vehicle Speed for Various Diesel Truck Groups from Contract 68-03-2147	139
73	Results of Regression Analysis for Emissions as a Logarithmic Function of Speed for Various Diesel Truck Groups from Contract 68-03-2147	141

LIST OF TABLES (cont'd)

Table		Page
74	Results of Regression Analysis for CO Emissions as a Logarithmic Function of Speed for Various Diesel Truck Groups from Contract 68-03-2147	142
75	Results of Regression Analysis for NO_x Emissions as a Logarithmic Function of Speed for Various Diesel Truck Groups from Contract 68-03-2147	143
76	Results of Regression Analysis for Fuel Consumption as a Logarithmic Function of Speed for Various Diesel Truck Groups from Contract 68-03-2147	144
77	Average Emissions from the 20 mph Transient Cycle for Trucks Tested under Contract 68-03-2147	145
78	Results of Regression Analysis for Emissions and Fuel Rate as a Function of Mileage and Weight/CID for Two Diesel Truck Groups	146
79	Results of Regression Analysis for Emissions and Fuel Rate as a Function of Weight and Weight/CID for Various Diesel Truck Groups	148
80	Average Test Weights for Various Diesel Truck Groups from Contract 68-03-2147	149
81	Average Percent Time Spent in Various Engine rpm-Manifold Vacuum Conditions for All Gasoline Trucks from Los Angeles and New York	152
82	Average Percent Time Spent in Various Engine rpm-Manifold Vacuum Conditions for All 26 Gasoline Trucks from Los Angeles CAPE-21 Study	153
83	Average Percent Time Spent in Various Engine rpm-Manifold Vacuum Conditions for 20 Single Unit Gasoline Trucks from Los Angeles CAPE-21 Study	154
84	Average Percent Time Spent in Various Engine rpm-Manifold Vacuum Conditions for Six Gasoline Tractor-Trailers from Los Angeles CAPE-21 Study	155
85	Average Percent Time Spent in Various Engine rpm-Manifold Vacuum Conditions for All 35 Gasoline Trucks from New York CAPE-21 Study	156
86	Average Percent of Time Spent in Various Engine rpm-Manifold Vacuum Conditions for 31 Single Unit Gasoline Trucks from New York CAPE-21 Study	157

LIST OF TABLES (cont'd)

Table		Page
87	Average Percent Time Spent in Various Engine rpm-Manifold Vacuum Conditions for Four Gasoline Tractor-Trailers from New York CAPE-21 Study	158
88	CAPE-21 Gasoline Trucks Average Percent Time Spent in Modes of 9-Mode FTP	167
89	Summary of 9-Mode Weighting Factors Calculated from CAPE-21 Data	169
90	Comparison of 9-Mode BSFC and LA-4 Fuel Economy for Six Trucks Tested under Contract 68-01-0472	170
91	Average Estimated Percent Fuel Used in Given rpm-Manifold Vacuum Intervals for All CAPE-21 Trucks (New York and Los Angeles)	174
92	Average Estimated Percent Fuel Used for the Six Manifold Vacuum Modes of the 9-Mode FTP	175
93	Comparison of 9-Mode BSFC and LA-4 Fuel Economy for Six Trucks Tested under Contract 68-01-0472	175
94	Percent of CAPE-21 Truck Operating Time Represented by Various Engine Speed and Manifold Vacuum Modes (All Trucks from New York and Los Angeles)	184
95	Percent Time in Percent Power and Percent Engine Speed Intervals for All Diesel Trucks Tested in CAPE-21 Study	188
96	Percent Time in Percent Power and Percent Engine Speed Intervals for All Los Angeles Diesel Trucks Tested in CAPE-21 Study	189
97	Percent Time in Percent Power and Percent Engine Speed Intervals for Los Angeles Single Unit Diesel Trucks Tested in CAPE-21 Study	190
98	Percent Time in Percent Power and Percent Engine Speed Intervals for Los Angeles Tractor-Trailer Diesel Trucks Tested in CAPE-21 Study	191
99	Percent Time in Percent Power and Percent Engine Speed Intervals for All New York Diesel Trucks Tested in CAPE-21 Study	192

LIST OF TABLES (cont'd)

Table		Page
100	Percent Time in Percent Power and Percent Engine Speed Intervals for New York Single Unit Diesel Trucks Tested in CAPE-21 Study	193
101	Percent Time in Percent Power and Percent Engine Speed Intervals for New York Tractor-Trailer Diesel Trucks Tested in CAPE-21 Study	194
102	Average Percent Time Spent in Modes of the 13-Mode FTP for CAPE-21 Diesel Trucks	199
103	Summary of 13-Mode Weighting Factors Calculated from CAPE-21 Data	200
104	Comparisons of 13-Mode BSFC Using Different Weighting Factors for 12 Diesel Trucks	202
105	Rated Power for 12 Diesel Trucks Tested under Contract 68-03-2147	205
106	Composite 13-Mode Fuel Rate Using Three Sets of Weighting Factors for 12 Diesel Trucks	210
107	Percent of CAPE-21 Truck Operating Time Represented by Various Percent Engine Speed and Percent Power Modes	215

I. INTRODUCTION

This report contains the results of the latest in a series of studies conducted by Southwest Research Institute (SwRI) on emissions from engines used to power trucks and buses above 2122 kg (6000 lbs) gross vehicle weight (GVW). The reports of these studies(1-14)* cover work done at Southwest Research Institute starting in 1967 on behalf of the Environmental Protection Agency (EPA) and its predecessor, the National Air Pollution Control Administration. This report presents the analysis of two main data bases for certain specific items required by EPA as part of their overall effort to control heavy-duty engine emissions. The report contains only the results of Phase I of a two-phase project entitled "Heavy-Duty Fuel Economy Program," EPA Contract 68-03-2220. The second phase of the project involving laboratory testing of some recent developments in engine systems will be reported in a separate volume upon completion of that phase.

A. Objectives

Phase I of the project has two tasks which, while interrelated, have separate objectives. The two tasks are a data analysis task and a weighting factor determination task. The objective of the data analysis task was to provide the EPA with answers to 10 specific items involving fuel consumption and emissions from both gasoline and diesel powered trucks. The data for the analysis was mainly from EPA Contract 68-03-2147, "Study of Emissions from Heavy-Duty Vehicles," supplemented by data from other studies where necessary. The objective of the second task is to develop modal coefficients for both the 9-mode heavy-duty gasoline and 13-mode heavy-duty diesel emissions tests that would correlate the 9 and 13-mode BSFC values to fuel economy of trucks in actual use. The results of the CAPE-21 study(15) were to be used in the development of the modal coefficients.

B. Report Organization

The main body of this report is divided into five sections. The first section describes the various data bases used in the analysis as well as describing the statistical computer programs used. The next two sections contain the results of the data analysis task of this phase, one section for gasoline-powered truck results and one section for diesel truck results. The last two sections contain the analysis done to obtain fuel consumption modal coefficients from the CAPE-21 information; one section contains the 9-mode gasoline truck analysis and the other section contains the 13-mode diesel analysis.

---

* Superscript numbers in parentheses designate List of References at end of this report.

II. DATA BASES AND STATISTICAL METHODS

This section describes the various data bases used as well as describing the statistical computer programs used and some of the special statistical techniques.

A. Data Bases

There were three main data bases used for this study. In addition, data from several other studies were used as required. The following paragraphs briefly describe each of the data bases used.

Thirty Truck Study

Data from this study was used in the data analysis task of Phase I. In this project, fuel consumption and exhaust emissions data were obtained from heavy-duty vehicles operated on chassis dynamometers. A total of 30 trucks were evaluated, ranging from 7700 kg (17,000 lbs) to 33,000 kg (73,000 lbs) GVW. The vehicles included 18 gasoline trucks (or truck-tractors) and 12 diesel trucks (or truck-tractors). The evaluations involved an on-the-road determination for setting dynamometer power and the evaluation on chassis dynamometers of several steady-state, sinusoidal and driving cycle operating conditions. Chassis version 9-mode or 13-mode evaluations were conducted as appropriate on all vehicles. Each of the vehicles was evaluated at three inertia weights and dynamometer road-load settings to simulate an empty vehicle, half payload, and full rated GVW. On two gasoline and two diesel vehicles, the entire emissions test sequence was repeated and determinations were made using alternate driving cycles. This work was performed under Contract 68-03-2147, titled "Study of Emissions From Heavy-Duty Vehicles." All tests in this study were conducted on a chassis dynamometer. Throughout this report, where data from this study is used, the word "dynamometer" is to be understood to mean chassis dynamometer.

Descriptions of the trucks used in this study are contained in Appendix A. Fuel consumption and emission results in terms of grams per minute were used throughout the data analysis task. For fuel consumption and emissions results for individual trucks in this study, refer to the project final reports.(13, 14) Reference 13 contains all of the tests results from the gasoline trucks and the results of the cycle testing on the chassis dynamometer for the diesel trucks. Reference 14 contains the results of the diesel 13-mode tests conducted on the 12 diesel trucks.

Truck Driving Pattern and Use Survey (CAPE-21)

Truck operation data from this study were used in the weighting factor determination task of Phase I. The study was conducted under the auspices of the Coordinating Research Council, Inc. and designated CRC Project No. CAPE-21-71. The January 1976 CRC APRAC Status Report describes the project as follows:

"Objective

The objective of this project is to develop background information on heavy-duty truck traffic patterns and use in major urban areas to allow formulation of a recommendation for an average truck driving cycle to be used in future emission testing programs.

Current Status

In the first phase, of this two-phase program, Wilbur Smith and Associates compiled available information on truck characteristics, type of industry, trip characteristics relating the intensity of truck use and location within the New York and Los Angeles urban areas. Final reports documenting the Phase I New York and Los Angeles studies have been published.

In Phase II the results of Phase I were used to select and categorize heavy-duty vehicles for the purpose of instrumenting and operating a sample of one hundred trucks representative of the total truck population in New York City and the Los Angeles Basin areas. Wilbur Smith and Associates conducted the New York City survey while the Environmental Protection Agency conducted the Los Angeles survey.

Each vehicle was instrumented for one week maximum, although lesser periods were used contingent upon the observed day-to-day route and use pattern variation, the availability of the truck, and the effect of seasonal variations. Engine rpm, vehicle speed, load factor, engine water temperature, and time were recorded at a rate of each data point per 0.8 second. In addition, a daily log was kept of the average daily ambient pressure and temperature; road conditions; and a subjective indication of traffic, route and operational conditions.

A Phase II final report covering the New York City field survey is scheduled for publication in 1976 and will conclude the CRC study. The Phase II Los Angeles field survey report will be published by the Environmental Protection Agency."(15)

Descriptions of the trucks tested under the CAPE-21 project are also contained in Appendix A.

San Antonio Road Route Studies

Data from these studies were used for comparison purposes in the data analysis task of Phase I. The San Antonio Road Route studies comprised three projects undertaken for the EPA. In the first study, the fuel economy, exhaust mass emissions, and operational performance of 25 gasoline-powered trucks from model years 1970 through 1972 were obtained during operation on a 7.24 mile course in San Antonio, Texas, using a constant volume sampler. This work was performed under EPA Contract 70-113.(7) The second study obtained the same information from 10 diesel trucks, model years 1970 through 1973 over the same road course. This study was done under EPA Contract 68-01-2113.(11) The third study obtained the fuel economy, mass emissions and operational performance from a group of 10 pre-controlled (pre-1970) gasoline-powered trucks over the same road course. This project was conducted under EPA Contract 68-03-0441.(12)

Descriptions of each set of trucks are contained in Appendix A. For fuel consumption, emmisions and operational data for individual trucks, see the final reports for the projects.(7,11,12) The final report for the 10 pre-controlled gasoline-powered trucks (Contract 68-03-0441) also contains comparisons of the results from the three studies.

Other Studies

It was necessary to make limited use of data from other studies. Data from the Ethyl Truck and Bus Study (ETABS) was used for comparison purposes in both the data analysis and weighting factor determination tasks. This study was conducted under Public Health Service Contract PH-86-62-12, "Survey of Truck and Bus Operating Modes in Several Cities." For details of the study, refer to the project final report.(16) The present study also made use of a previously unpublished EPA analysis of the raw data from the ETABS project. This EPA analysis, in the form of a set of curves, is included in this report as Appendix F.

Data from two other studies done at SwRI was used in the weighting factor determination task. One of these studies contained complete fuel consumption and emission maps of four truck engines as part of a broad study of gasoline-powered truck emissions under EPA Contract 70-110. For details of the project, refer to the final report.(5) The other study contined fuel consumption and emissions from six truck engines tested on an engine dynamometer and then installed in truck chassis and tested on a chassis dynamometer. This work was part of a heavy-duty emission control technology study performed for the EPA under contract 68-01-0472. For details of the project, refer to Reference 10.

B. Statistical Methods

Where possible, standard statistical computer program packages were used for both tasks of Phase I. The two primary computer programs used were the UCLA Biomedical Statistical Programs (BMD) and the Statistical Package for the Social Sciences (SPSS). These package programs are in general use throughout the country and most statisticians are familiar with their contents. Where no mention is made of the computer program used in an analysis, it is understood that one of these two programs was used.

Occasionally it was necessary to develop a special program in order to perform the required analysis for a given item. Where this is done, the features and use of the program are explained with the results of the analysis. Fortran listings of these special programs are included in Appendix A.

III. GASOLINE TRUCK CYCLE ANALYSIS

This section covers the results of the analysis of 10 specific items requested by the EPA. These items of analysis used the fuel consumption and emissions data in grams per minute obtained by SwRI under Contract 68-03-2147, "Study of Emissions from Heavy-Duty Vehicles." A familiarity with the contents of the reports generated by that Contract (References 13 and 14) is essential in understanding the analysis contained in this section. Other data bases were sometimes used to supplement this data. Each of the 10 items will be covered separately in the following paragraphs.

Item 1 - How well does test-to-test variability of a cycle compare with cycle-to-cycle variability for cycles of the same average speed? For all cycles?

The data from the two gasoline-powered trucks (Nos. 17 and 18) that ran replicate tests were used to answer this question. An analysis of variance (ANOVA) was run for fuel rate, HC, CO, and NO_x for each of the three vehicle loads (empty, half, and full) tested. The steady-state, sinusoidal, and transient driving cycles were compared at common average speed designations of 5, 10, 15, 20, 30, and 40. These speed designations correspond to speeds of 8, 16, 24, 32, 48 and 64 kilometers per hour (kph), respectively. Only at 32 kph were all three types of cycles (steady state, sinusoidal and driving) used. At the other speeds, only two of the three cycle types were used. The ANOVA was a partially nested analysis in that the replicates were nested within truck number.

Additional sources of variation in the data included effects due to replicates within each truck and truck-by-cycle interaction. The effects due to replicates within each truck were assumed to be random. If the truck-by-cycle interaction was non-significant, then the truck-by-cycle sum of squares was pooled with that of the cycle by replication-within-truck interaction to increase the error degrees of freedom. The cycle by replication-within-truck interaction was also assumed to be negligible to allow a test for significant difference between tests.

The 72 results (three emissions and fuel consumption at each of six speeds for three different loads) of tests for significant differences between cycles and between tests-within-truck are given in Appendix B as Tables B-1 through B-4. It appears that, in general, the cycles differ significantly among themselves (except for the 64 kph tests), while the tests show relatively no change. This is further supported by measurements of the actual variability. The upper values in each table represent the cycle variability, (MSC-MSE)/N;* while the lower numbers are the test-to-test variability, (MSR(T)-MSE/2.* It is again evident that the cycle-to-cycle variability far exceeds the test-to-test variability. Where an

---

*MSC - mean square cycle (i.e., cycle sum of square/deg. of freedom)
MSE - mean square error
MSR(T) - mean square replication within truck (i.e., tests with truck sum of square/deg. of freedom)
N - sample size

F test on the truck-by-cycle interaction indicated no significance, the pooled MSE was used, otherwise the unpooled MSE corresponding to cycle by replication within truck variation was used.

The purpose of this analysis is to try and gain some indication of whether or not emission differences between different cycles at the same average speed are real or just the result of test-to-test variations. One way to determine this is to compare the significance of the F ratio from the test-to-test and cycle-to-cycle variations given in Appendix Tables B-1 through B-4. There are, of course, four possible combinations. The test-to-test variation can be not significant and the cycle-to-cycle variation can be either significant or not significant; or the test-to-test variation can be significant and the cycle-to-cycle variation can be either significant or not significant.

If the test-to-test variation is not significant, then the cycle-to-cycle variation can be evaluated with some degree of assurance that test-to-test variation is not unduly influencing the conclusions. If, however, the test-to-test variation is significant, the evaluation of emissions differences between cycles becomes more difficult. If the cycle-to-cycle variation is not significant, while the test-to-test variability is, then it is probably safe to conclude that there is no significant variation in that emission (or fuel consumption) between cycles. If the cycle-to-cycle variation is significant, then it is not possible to ascertain what part of the difference is due to test-to-test variability and what part is due to the cycle-to-cycle variation.

In the analysis of the gasoline results, the 24 kph empty load NO_x and the 8 kph full load fuel, had significant test-to-test variation. Both of these conditions had significant cycle-to-cycle variations as well. This fact should be kept in mind when using the analyses presented in this report.

In summary, it appears that for all but a few of the test cycles, test-to-test repeatability was not significant so that emission and fuel changes between cycles of the same speed can be evaluated. It should be pointed out in closing this discussion that the evaluation of the test-to-test variability was based on an absolute minimum of data (two replicate tests on two trucks). Thus, the results of this analysis should be used with care.

Item 2 - How well can fuel consumption and emissions measured by the present 9-mode FTP predict the fuel consumption and emissions over other cycles?

For this item, the data for the nine single axle gasoline-powered trucks were used so that differences due to truck type would not complicate the analysis. The first analysis done was to obtain a correlation matrix to determine the correlation between the 9-mode FTP fuel and emission rates (for composite 9-mode results, as well as each individual mode) and the fuel and emission rates from the other driving cycles. This was done for each of the three vehicle test loads separately. Throughout the discussion of this item and the items that follow, it should be kept in mind that all emissions, whether modal, composite 9-mode, or a chassis dynamometer test cycle, are expressed in grams/minute since this was how the data was furnished from Contract 68-03-2147. Tables 1, 2, and 3 show part of the results of this correlation matrix. Only correlations of like variables with correlation coefficients above 0.9 are shown and no correlations between modes of the 9-mode test are shown. From the tables, it can be seen that only the composite 9-mode HC emissions, of all the 9-mode composite emissions, correlate well to the transient emissions. The empty and half load 9-mode composite fuel rate did correlate with the idle fuel rate, but not to any of the driving cycles. While individual variables for each mode will correlate with various test cycles, there is no one mode in which all of the emissions and fuel rate correlate with any of the driving test cycles.

Since the composite 9-mode emissions are normally of the most interest, Table 4 presents the correlation coefficients of the composite 9-mode emissions or fuel rate and the same variable from the other test cycles. As can be seen from the table, there is, in general, a strong, positive linear trend for most of the cycle emissions. However, only a few of the cycle emissions have correlation coefficients sufficiently large to use the composite 9-mode results to predict actual vehicle emissions. This being the case, no regression coefficients were obtained for any of the cycles. For a description of the cycles, see Reference 13. A list of the different cycles used is included in Appendix A as Tables A-9 and A-10.

A step-wise multiple regression analysis using a forward selection procedure was performed using emissions and fuel rate from three of the four transient driving cycles and the 32 and 48 kph sinusoidal cycle as functions of the modal emissions and fuel rate from the 9-mode test. The significance levels for both inclusion or exclusion of the modes were set at 0.05. In this analysis, a zero intercept was assumed, but the modal coefficients (weighting factors) were not constrained to be positive nor were they contrained to sum to 1.0. The analysis showed that many of the modal emissions and fuel rate were highly correlated with other modes, particularly for fuel rate. This does not mean that some of the modes are not important, only that for this particular set of nine trucks, some of the modal emissions (or fuel rate) are a multiple (possibly plus a constant) of other modes. With a different set of trucks these correlations could change. The correlation coefficients between modes are shown in Table 5.

The modal regression coefficients relating the modal emissions and fuel rate to the various dynamometer cycle emissions and fuel rate are contained in Tables B-5 to B-8 of Appendix B. The modal coefficients are shown to the 0.05 significance level. Generally, this required two modes, although sometimes one and sometimes three modes were used. The coefficients of determination (r^2) given in Tables B-5 to B-8 should not, in general, be directly compared with the correlation coefficients (r) given in Table 4. The correlation coefficients in Table 4 reflect the correlation between one independent variable (9-mode composite emission or fuel rate) and one dependent variable (cycle emission or fuel rate). The coefficients of determination in Tables B-5 to B-8, on the other hand, generally reflect the correlation between two or more independent variables, and the one dependent variable.

TABLE 1. RELATIONSHIPS BETWEEN MODAL AND CHASSIS DYNAMOMETER CYCLE EMISSIONS HAVING CORRELATION COEFFICIENTS ABOVE 0.9 FOR EMPTY LOAD TESTS (ALL VARIABLES IN TERMS OF GRAMS/MINUTE)
SAMPLE SIZE: NINE SINGLE AXLE GASOLINE TRUCKS

I. Composite 9-mode Average

HC	CO	NO_x	Fuel Rate
	Correlates with:		
32 kph sine HC		24 kph trans. NO_x	0 kph S/S Fuel
16 kph trans. HC			
24 kph trans. HC			
32 kph trans. HC			

II. Mode 1 (Idle)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
0 kph S/S HC			
48 kph sine HC			
8 kph trans. HC			
16 kph trans. HC			
24 kph trans. HC			
32 kph trans. HC			

III. Modes 2, 4, 6, 8 (16" of mercury manifold vacuum)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
48 kph S/S HC	32 kph S/S CO		0 kph S/S Fuel
	48 kph S/S CO		64 kph S/S Fuel
	48 kph sine CO		8 kph trans. Fuel
	16 kph S/S CO		16 kph trans. Fuel
	24 kph S/S CO		

IV. Mode 3 (10" of mercury manifold vacuum)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
64 kph S/S HC			64 kph S/S Fuel

V. Mode 5 (19" of mercury manifold vacuum)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
16 kph S/S HC			48 kph S/S Fuel
24 kph S/S HC			8 kph trans. Fuel
88 kph S/S HC			

VI. Mode 7 (3" of mercury manifold vacuum)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
		16 kph trans. NO_x	

VII. Mode 9 (closed throttle)

No correlations

TABLE 2. RELATIONSHIPS BETWEEN MODAL AND CHASSIS DYNAMOMETER CYCLE EMISSIONS HAVING CORRELATION COEFFICIENTS ABOVE 0.9 FOR HALF LOAD TESTS (ALL VARIABLES IN TERMS OF GRAMS/MINUTE) SAMPLE SIZE: NINE SINGLE AXLE GASOLINE TRUCKS

I. Composite 9-mode Average

HC	CO	NO_x	Fuel Rate
	Correlates with:		
32 kph sine HC			0 kph S/S Fuel
48 kph sine HC			
16 kph trans. HC			
24 kph trans. HC			
32 kph trans. HC			

II. Mode 1 (Idle)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
0 kph S/S HC			0 kph S/S Fuel
8 kph trans. HC			
16 kph trans. HC			
24 kph trans. HC			

III. Mode 2, 4, 6, 8 (16" of mercury manifold vacuum)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
32 kph S/S HC	16 kph S/S CO		0 kph S/S Fuel
16 kph S/S HC	24 kph S/S CO		64 kph S/S Fuel
	32 kph sine CO		8 kph trans. Fuel
	0 kph S/S CO		
	48 kph S/S CO		
	8 kph S/S CO		

IV. Mode 3 (10" of mercury manifold vacuum)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
64 kph S/S HC		64 kph sine NO_x	64 kph S/S Fuel

V. Mode 5 (19" of mercury manifold vacuum)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
24 kph S/S HC	8 kph S/S CO		64 kph S/S Fuel
			32 kph sine Fuel
			8 kph trans. Fuel

VI. Mode 7 (3" of mercury manifold vacuum)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
		16 kph trans. NO_x	

VII. Mode 9 (closed throttle)

No correlations

TABLE 3. RELATIONSHIPS BETWEEN MODAL AND CHASSIS DYNAMOMETER CYCLE EMISSIONS HAVING CORRELATION COEFFICIENTS ABOVE 0.9 FOR FULL LOAD TESTS (ALL VARIABLES IN TERMS OF GRAMS/MINUTE) SAMPLE SIZE: NINE SINGLE AXLE GASOLINE TRUCKS

I. Composite 9-mode Average

Correlates with:

HC	CO	NO_x	Fuel Rate
32 kph sine HC			
48 kph sine HC			
16 kph trans. HC			
24 kph trans. HC			
32 kph trans. HC			

II. Mode 1 (Idle)

Correlates with:

HC	CO	NO_x	Fuel Rate
8 kph trans. HC	0 kph S/S CO		0 S/S Fuel
16 kph trans. HC			
24 kph trans. HC			
32 kph trans. HC			

III. Modes 2, 4, 6, 8 (16" of mercury manifold vacuum)

Correlates with:

HC	CO	NO_x	Fuel Rate
16 kph S/S HC	8 kph S/S CO		64 kph S/S fuel
	16 kph S/S CO		8 kph trans. fuel
	24 kph S/S CO		
	32 kph S/S CO		
	48 kph S/S CO		

IV. Mode 3 (10" of mercury manifold vacuum)

Correlates with:

HC	CO	NO_x	Fuel Rate
64 kph S/S HC	64 kph S/S NO_x	64 kph S/S NO_x	64 kph S/S Fuel

V. Mode 5 (19" of mercury manifold vacuum)

Correlates with:

HC	CO	NO_x	Fuel Rate
8 kph S/S HC	8 kph S/S CO		
24 kph S/S HC	16 kph S/S CO		
	24 kph S/S CO		

VI. Mode 7 (3" of mercury manifold vacuum)

Correlates with:

HC	CO	NO_x	Fuel Rate
		16 kph trans. NO_x	

VII. Mode 9 (closed throttle)

No correlations

TABLE 4. CORRELATION COEFFICIENTS BETWEEN FTP RESULTS AND DRIVING CYCLE RESULTS FOR NINE SINGLE AXLE GASOLINE TRUCKS

Test	Empty Load				Half Load				Full Load			
Desc.	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel
00 SS	0.838	0.767	-0.504	0.941	0.715	0.727	0.307	0.947	0.538	0.677	-0.809	0.895
05 SS	0.242	0.877	0.058	0.341	-0.117	0.882	0.281	0.497	0.192	0.890	0.177	0.558
10 SS	0.382	0.825	0.596	0.608	0.436	0.845	0.642	0.599	0.520	0.816	0.584	0.604
15 SS	0.078	0.856	0.400	0.750	0.031	0.850	0.530	0.791	0.053	0.852	0.385	0.754
20 SS	0.439	0.806	0.775	0.766	0.476	0.812	0.800	0.751	0.649	0.736	0.749	0.774
30 SS	0.556	0.715	0.654	0.772	0.552	0.671	0.761	0.735	0.595	0.560	0.768	0.774
40 SS	0.410	0.428	0.544	0.875	0.290	0.218	0.521	0.869	0.362	0.146	0.679	0.868
55 SS	-0.230	0.299	0.672	0.637	0.162	0.195	0.735	0.342	0.285	-0.098	0.857	0.178
20±5	0.934	0.515	0.832	0.712	0.915	0.781	0.822	0.754	0.937	0.470	0.845	0.673
30±5	0.837	0.805	0.818	0.589	0.947	0.808	0.857	0.702	0.951	0.737	0.862	0.423
40±2	0.403	0.657	0.527	0.685	0.378	0.579	0.604	0.741	0.377	0.549	0.673	0.487
05 Avg.	0.860	0.784	0.564	0.865	0.884	0.809	0.760	0.866	0.890	0.803	0.683	0.899
10 Avg.	0.953	0.819	0.802	0.803	0.939	0.877	0.787	0.814	0.966	0.846	0.757	0.829
15 Avg.	0.933	0.834	0.941	0.656	0.948	0.794	0.886	0.743	0.960	0.867	0.851	0.500
20 Avg.	0.934	0.771	0.762	0.695	0.941	0.687	0.829	0.610	0.964	0.816	0.861	0.547

TABLE 5. CORRELATION COEFFICIENTS BETWEEN THE MODES OF THE 9-MODE GASOLINE HEAVY-DUTY FTP

Mode	Condition	Idle	16"	10"	19"	3"	CT
			HC Emissions				
1	Idle	1.000	0.905	0.852	0.651	0.871	0.821
2,4,6,8	16"		1.000	0.924	0.845	0.942	0.836
3	10"			1.000	0.605	0.934	0.840
5	19"				1.000	0.683	0.550
7	3"					1.000	0.868
9	CT						1.000
			CO Emissions				
1	Idle	1.000	0.867	0.747	0.845	0.651	0.978
2,4,6,8	16"		1.000	0.881	0.953	0.758	0.862
3	10"			1.000	0.803	0.682	0.804
5	19"				1.000	0.800	0.818
7	3"					1.000	0.641
9	CT						1.000
			NO_x Emissions				
1	Idle	1.000	0.674	0.691	0.617	0.690	0.909
2,4,6,8	16"		1.000	0.951	0.754	0.745	0.767
3	10"			1.000	0.682	0.803	0.801
5	19"				1.000	0.676	0.580
7	3"					1.000	0.724
9	CT						1.000
			Fuel Consumption				
1	Idle	1.000	0.983	0.982	0.980	0.971	0.973
2,4,6,8	16"		1.000	1.000	1.000	0.995	0.977
3	10"			1.000	0.999	0.994	0.977
5	19"				1.000	0.995	0.976
7	3"					1.000	0.964
9	CT						1.000

Sample size - Nine single axle gasoline trucks

To obtain correlation coefficients from the stepwise regressions to compare with Table 4, the composite emissions or fuel rate would first have to be calculated using the coefficients in Tables B-5 to B-8 and a regression performed using the composite emission and the dynamometer cycle emission. Of course, where only one mode was used in the stepwise regression, it is the composite value and the square root of its coefficient of determination can be compared with the corresponding correlation coefficient in Table 4.

From an engineering standpoint, there are many problems with using only one or two discrete points of engine operation to predict the emissions and fuel rate when the engine is in a vehicle and operating over a wide range of speed and power. First, the data represents only 9 trucks operating at certain vehicle weights and vehicle weight to engine power ratios. Other trucks, vehicle weights and weight/power ratios could have different relationships. Secondly, the relationship between one engine operating point and other operating points is very much subject to change as emissions regulations and fuel economy pressures cause changes in engine design and operational schedules of ignition, carburetion, and emission control systems. For these reasons, a table similar to Table 4 was not prepared for the stepwise regression results.

The stepwise regression results can be used to determine which of the modes or combination of modes best predicts emissions and fuel for the vehicle cycles. Table 6 shows the order that each mode was entered for each emission type and each test cycle. For each emission type there is normally one mode which generally entered first. For HC, the idle mode enters first for the transient cycles and the closed throttle mode generally enters first for the sinusoidal cycles. For CO, the 16 inch mode enters first most often. For NO_x, either the 10 inch or 3 inch mode is entered first. For fuel rate, the mode that enters first is split between the 16 inch, 19 inch and 3 inch mode, with the 19 inch mode being first most often.

To determine if the nine modes could be reweighted to obtain a new set of composite values which would better correlate to driving cycles, with the constraints that the weighting factors be positive and that they sum to 1.0, a special analysis was performed. As was suggested by EPA, linear programming techniques were used to obtain modal coefficients that were constrained to be positive and sum to 1.0. The computer program used was based on Lemke's complementary pivot method to solve the quadratic minimization of $\Sigma(y-\hat{y})^2$. The actual computer algorithm was obtained from Reference 17. A Fortran listing of the program used is included in Appendix A. The quadratic program solutions are contained in Appendix B as Tables B-9 through B-12 for HC, CO, NO_x, and fuel rate, respectively. The form of the equation is:

$$Y = AX_1 + BX_2 + CX_3 + DX_4 + EX_5 + FX_6$$

where Y is driving cycle HC, CO, NO_x or fuel rate.

X_1, X_2, X_3, etc., are individual modal values of HC, CO, NO_x or fuel rate.

A, B, C, etc., are the regression coefficients for the individual modes.

TABLE 6. ORDER OF ENTRY IN STEPWISE MULTIPLE REGRESSION FOR INDIVIDUAL MODES OF THE GASOLINE HEAVY-DUTY 9-MODE FTP FOR NINE GASOLINE TRUCKS

Test Cycle		HC Emissions						CO Emissions						Test Cycle	
		Idle	16"	10"	19"	3"	CT	Idle	16"	10"	19"	3"	CT		
							Empty Load								
Transient	10	1	5	6	3	4	2	3	1	4	6	2	5	Transient	10
	15	1	4	3	5	6	2	3	1	4	6	2	5		15
	20	1	3	6	5	4	2	3	6	2	5	1	4		20
Sinusoidal	20	2	4	7	5	3,R*6,8	1	3	1	2	6	4	5	Sinusoidal	20
	30	2	4	3	5	1	6	5	1	4	6	3	2		30
							Half Load								
Transient	10	1	5	6	3	4	2	3	1,R*6	4	7	2	5	Transient	10
	15	1	3	5	4	6	2	2	1	4	6	3	5		15
	20	1	3	4	5	6	2	4	6	3	5	1	2		20
Sinusoidal	20	2	5	4	6	3	1	4	5	2	1	3	6	Sinusoidal	20
	30	2	6	4	5	3	1	6	1	4	5	2	3		30
							Full Load								
Transient	10	1	4	3	5	6	2	4	1	3	6	2	5	Transient	10
	15	1	3	5	4	6	2	5	1	3	6	2	4		15
	20	1	3	6	5	4	2	5	2	3	6	1	4		20
Sinusoidal	20	2	4	3	5	6	1	4	5	1	3	2	-	Sinusoidal	20
	30	2	4	3	5	6	1	4	3	2	6	1	5		30

Test Cycle		NO_x Emissions						Fuel Rate						Test Cycle	
		Idle	16"	10"	19"	3"	CT	Idle	16"	10"	19"	3"	CT		
							Empty Load								
Transient	10	4	5	2	3	1	6	4	1	-	-	3	2	Transient	10
	15	4	6	1	3	2	5	3	-	-	1	4	2		15
	20	5	4	1	3	2	6	3	-	-	1	4	2		20
Sinusoidal	20	5	6	1	3	2	4	3	-	-	1	2	4	Sinusoidal	20
	30	4	6	1	5	2	3	4	-	-	1	3	2		30
							Half Load								
Transient	10	3	2	4	5	1	6	4	1	-	-	3	2	Transient	10
	15	4	6	1	3	2	5	4	-	-	1	3	2		15
	20	5	4	1	3	2	6	4	-	-	1	3	2		20
Sinusoidal	20	6	2	3	4	1	5	3	-	-	1	2	4	Sinusoidal	20
	30	6	2	5	4	1	3	3	-	-	1	2	4		30
							Full Load								
Transient	10	3	5	2	6	1	4	3	1	-	-	4	2	Transient	10
	15	3	5	1	6	2	4	4	2	-	-	1	3		15
	20	3	5	1	6	2	4	4	2	-	-	1	3		20
Sinusoidal	20	4	2	5	-	1	3	2	-	-	1	3	4	Sinusoidal	20
	30	3	2,R*7	5	4	1	6	2	-	-	1	4	3		30

---

* R means removed

It should be noted that while the gasoline heavy-duty emission test has nine modes, modes 2, 4, 6, and 8 are all at the same engine operating condition. These modes have been combined for this analysis, giving six separate modes. Note that a zero intercept was assumed. Also, it should be pointed out that if an unconstrained regression analysis results in any coefficients that are negative, a regression analysis which constrains the coefficients to be positive will have at least one zero coefficient.(21) The appendix tables present the equation coefficients, which are the modal weighting factors, except for the 16 inch mode, where the coefficient must be divided by four. There is a separate equation for each driving cycle and load for each emission or fuel rate.

While not listed in the tables, the correlation coefficients for these equations were all above 0.9. It should be clearly understood that this was not the correlation coefficient for a linear fit of the observed driving cycle emission to calculated composite 9-mode emission. Rather, the correlation coefficient reflects the fit of the driving cycle value to the six different modal values from the 9-mode test.

In order to obtain a better understanding of the usefulness of the new weighting factors, a linear regression was performed using the composite 9-mode results using the new weighting factors and the emissions or fuel consumption from the various driving cycles. The correlation coefficients are shown in Table 7.

In almost every case, the reweighted composite 9-mode value improved the correlation. In a few cases, the correlation coefficient from the reweighted values showed a slight decrease.

While reweighting did, in general, improve the correlation, it produces a different set of weighting factors for each driving cycle and emission combination. The 60 equations relating the reweighted 9-mode emissions and fuel rate to the driving cycle emissions and fuel rate are shown in Table 8. Whether these equations from the reweighted 9-mode emissions should be used to predict emissions from other cycles is a matter of judgment. However, it is felt that these correlations are still not good enough for all the uses to which these correlations might be subjected.

The reason that some of the reweighted correlation coefficients were lower than the FTP correlation coefficients remains unknown. However, since the purpose of the reweighting was to obtain the best possible set of weighting factors, a review of the method seemed in order. The quadratic programming technique used to reweight the modes was necessitated by the two constraints on the weighting factors requested by the EPA. One constraint was the weighting factor (which are the coefficients in the equation) must all be positive; the other was that the weighting factors sum to 1.0.

As a consequence of the least squares approach, the method necessarily tried to generate modal coefficients that would give composite emissions or fuel rate identically equal to the dynamometer test emission or fuel rate. In other words, an equation relating composite 9-mode and dynamometer test cycle emissions or fuel rate would have a slope of 1.0. However, it is not really necessary that the composite 9-mode value be equal

TABLE 7. CORRELATION COEFFICIENTS FROM REGRESSION ANALYSIS BETWEEN REWEIGHTED 9-MODE RESULTS AND DRIVING CYCLE RESULTS FOR NINE SINGLE AXLE TRUCKS

Test	Empty Load				Half Load				Full Load			
Desc.	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel
20±5	0.942	0.891	0.884	0.856	0.940	0.748	0.878	0.870	0.927	0.613	0.907	0.783
30±5	0.938	0.976	0.849	0.748	0.957	0.844	0.891	0.829	0.957	0.692	0.957	0.704
10 Avg.	0.975	0.868	0.980	0.887	0.939	0.885	0.983	0.863	0.944	0.668	0.903	0.869
15 Avg.	0.975	0.870	0.958	0.776	0.966	0.865	0.921	0.855	0.975	0.889	0.922	0.603
20 Avg.	0.960	0.754	0.869	0.785	0.932	0.783	0.920	0.735	0.939	0.849	0.938	0.675

TABLE 8. REGRESSION EQUATIONS RELATING REWEIGHTED COMPOSITE 9-MODE EMISSIONS AND FUEL RATE TO VARIOUS DRIVING CYCLE EMISSIONS AND FUEL RATE FOR NINE SINGLE AXLE GASOLINE TRUCKS

	Empty load			Half load			Full load		
Cycle	a	b	r	a	b	r	a	b	r
				HC Emissions					
20 ± 5	- 0.864	1.106	0.943	- 1.093	1.120	0.940	- 2.532	1.247	0.927
30 ± 5	0.178	0.961	0.938	- 0.645	1.086	0.957	- 0.840	1.101	0.957
10 avg.	- 0.155	1.059	0.975	0.023	1.031	0.939	- 1.554	1.284	0.944
15 avg.	0.134	0.984	0.975	0.035	1.001	0.966	0.037	1.019	0.952
20 avg.	0.376	0.946	0.960	0.107	1.001	0.932	0.076	1.035	0.939
				CO Emissions					
20 ± 5	- 4.590	1.226	0.891	0.360	1.086	0.748	27.163	0.695	0.613
30 ± 5	- 0.489	1.045	0.976	- 1.382	1.106	0.844	36.473	0.555	0.692
10 avg.	8.028	0.871	0.868	9.105	0.869	0.885	25.494	0.662	0.668
15 avg.	4.44	0.901	0.870	5.738	0.936	0.865	10.407	0.863	0.889
20 avg.	17.626	0.706	0.754	26.511	0.691	0.783	43.27	0.669	0.849
				NO_x Emissions					
20 ± 5	0.158	0.960	0.884	- 0.209	1.051	0.878	- 0.262	1.059	0.908
30 ± 5	- 0.171	1.047	0.849	- 0.449	1.108	0.891	0.067	0.994	0.957
10 avg.	0.128	0.915	0.980	0.190	0.889	0.981	0.513	0.705	0.903
15 avg.	0.526	0.783	0.958	0.596	0.760	0.921	0.599	0.778	0.922
20 avg.	0.992	0.734	0.869	0.535	0.851	0.920	0.996	0.706	0.938
				Fuel Rate					
20 ± 5	-87.426	1.532	0.856	-60.443	1.335	0.870	- 42.991	1.215	0.783
30 ± 5	-48.539	1.286	0.748	-47.213	1.256	0.829	-496.43	3.617	0.704
10 avg.	-20.886	1.187	0.887	- 4.253	1.034	0.863	- 13.181	1.098	0.869
15 avg.	18.159	0.855	0.776	- 4.413	1.034	0.855	18.830	0.871	0.603
20 avg.	26.374	0.842	0.785	34.447	0.813	0.735	- 2.491	1.011	0.675

---

form of equation: $Y = a + bx$

where: X = Reweighted composite 9-mode emission or fuel
Y = cycle emission or fuel
r = correlation coefficient

to the dynamometer test cycle value, only that it can predict the test cycle value. It was then realized that the constraint that the modal coefficients sum to 1.0 is an unnecessary constraint. It is possible to make any group of coefficients sum to 1.0 simply by summing the coefficients and dividing each individual coefficient and the dependent variable $\hat{y}$ by the sum of all the coefficients. To be sure, this changes the absolute value of the composite emission (or fuel rate); but it does not change the correlation coefficient of the equation. Thus, both constraints are not required to generate an optimum set of weighting factors.

Another way to obtain the best possible correlation between composite modal values and dynamometer test cycle values, is to use a non-linear regression analysis such as found in the UCLA BMD statistical program. This program allows all of coefficients to be constrained to positive values. The coefficients(and the composite values) can then be recalculated by dividing each of the coefficients and the composite values by the sum of the coefficients. It should be emphasized that the linear programming techniques used to generate the reweighted values contained in this section is not incorrect, it is simply overly restrictive since a regression with one constraint will give a better fit than a model with two constraints.

Since it was also requested that one set of weighting factors be obtained using all emissions and fuel consumption as if they were one variable it was decided to use the method of constraining the coefficients only to positive values then normalizing the coefficients to sum to one after the regression was performed to obtain this set of weighting factors.

The positive constrained regression coefficients for each test cycle are given in Appendix B as Table B-13. The normalized regression coefficients (normalized to sum to 1.0) are contained in Table B-14.

While obtaining correlation coefficients for reweighted 9-mode results completed the required analysis on this item, some further work was felt to be necessary on the fuel consumption relationship. Figure 1 is a plot of the 32 kph fuel rate as a function of the reweighted composite 9-mode fuel rate. The regression equation and coefficient of determination (r^2) are shown on the figure. The coefficient of determination of 0.54 indicates that this would be a poor relationship to use to predict 32 kph fuel rate from the composite 9-mode fuel rate.

Before proceeding further, it was felt that some examination of the reasons for the poor relationship between the fuel rates should be done. There are several factors that could influence the relationship. A mathematical reason has already been explained. There are also physical reasons. The modal fuel rates from the 9-mode test are a function of engine size as can be seen by Figure 2. While the 32 kph fuel rates were all for the half load condition, the actual test weight of each truck was different.

It was felt that perhaps normalizing the 9-mode modal fuel rates to one engine size and the 32 kph fuel rates to one test weight would give a better relationship. This was done and the quadratic optimization program rerun to obtain new 9-mode weighting factors. When the 32 kph fuel rate

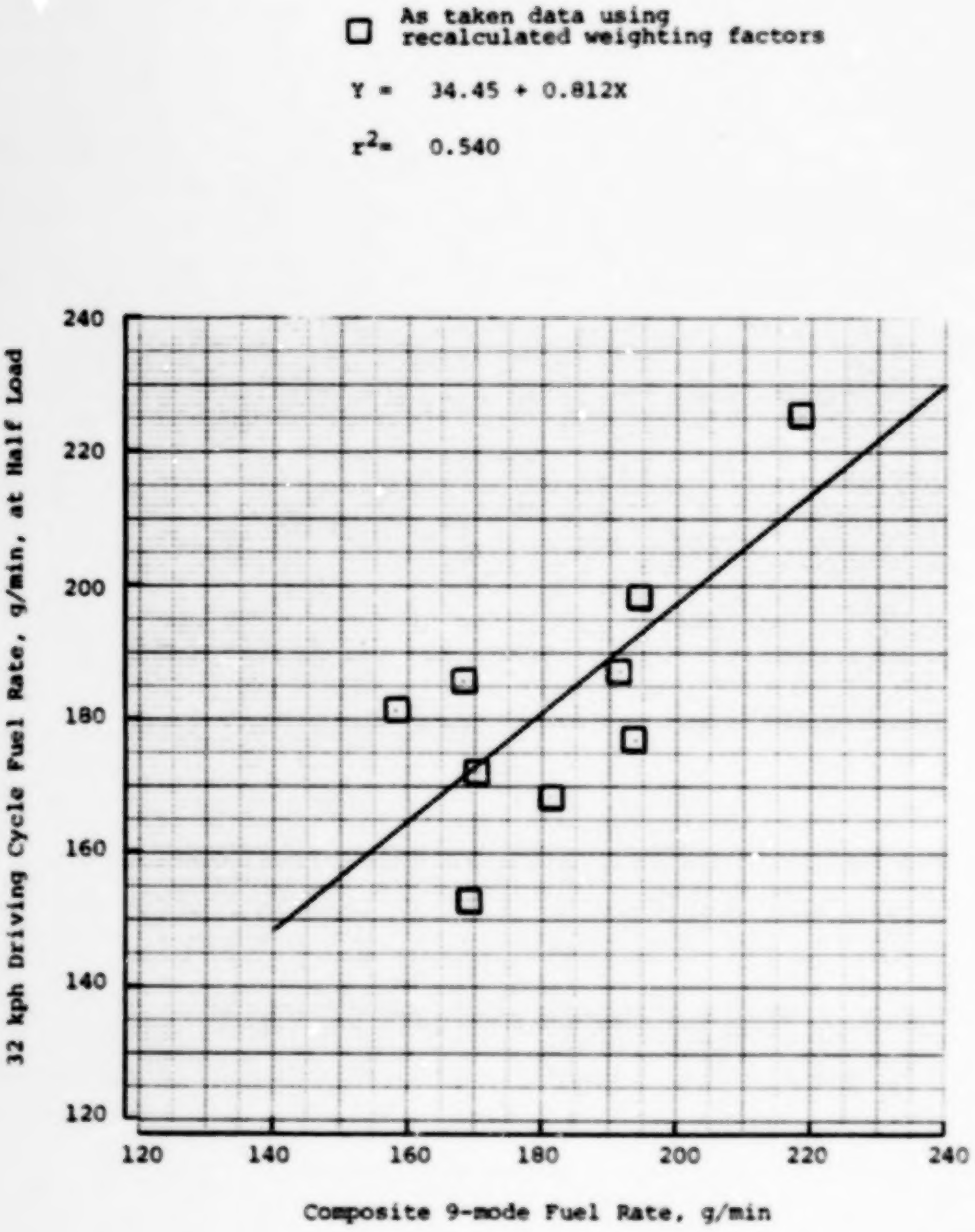
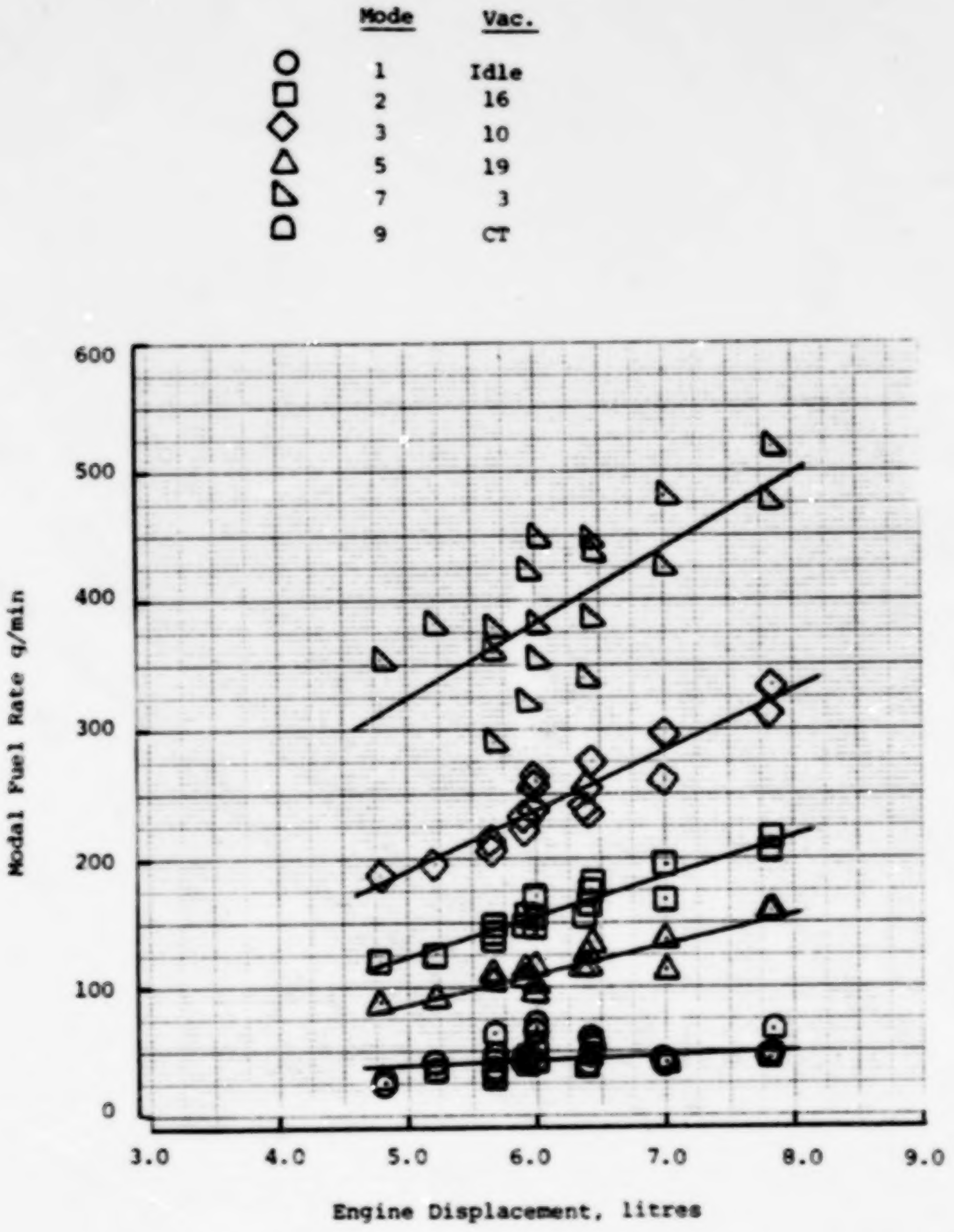


FIGURE 1. 32 KPH DRIVING CYCLE FUEL RATE VS. 9-MODE FUEL RATE FOR 9 SINGLE AXLE TRUCKS



	Mode	Vac.
○	1	Idle
□	2	16
◇	3	10
△	5	19
◺	7	3
D	9	CT

FIGURE 2. MODAL FUEL RATE VS. ENGINE DISPLACEMENT FOR 18 GASOLINE-POWERED TRUCKS

(taken at 7000 kg test weight) was plotted as a function of the new composite 9-mode fuel rate (normalized to 5.65 litres), the relationship was obviously so poor that no regression analysis was performed.

While plotting the 32 kph fuel rate versus test weight for the preceding analysis, an interesting characteristic was observed. For each engine size, the curve of 32 kph fuel rate versus test weight had a point of zero slope at some test weight (see Figure 3). Without examining the theoretical reasons for this, it was assumed that this point represented the same power-to-weight ratio or something similar for all trucks. When the fuel rate at this point was plotted against engine size, a strong linear relationship was found to exist (see Figure 4).

It was reasoned that perhaps the fuel rate at this particular vehicle weight could be predicted from 9-mode composite fuel rate since both were a function of engine size. The modal weighting factor optimization programs was again rerun using the 32 kph fuel rate at the vehicle weight where the fuel-rate vehicle weight curve had a zero slope. These values, taken from Figure 3, are shown in Table 9, together with the calculated 9-mode composite fuel rate and 32 kph fuel rate.

Figure 5 is the plot of the composite 9-mode fuel rate using the new optimized weighting factors and 32 kph fuel rate. The linear regression equation is also shown. This method greatly improves the relationship, giving a correlation coefficient of 0.916. This correlation coefficient can be compared with those obtained using empty, half, and full load shown in Table 2. The largest correlation coefficient for fuel rate and the 32 kph driving cycle in Table 2 was 0.783 for half load. The maximum variation of any of the nine single axle trucks is about 9 percent.

Bear in mind that the 32 kph fuel rates are at different vehicle weights depending on the size of the engine. However, with a knowledge of how the 32 kph fuel rate varies with vehicle weight for a given engine size, the fuel rate at any other vehicle weight could be predicted. To do this would be well beyond the scope of this project.

Since the weight-to-size ratio is a factor in relating 9-mode composite fuel rate to 32 kph transient fuel, it is possible that it is a factor for all transient cycle fuel rate relationships. Whether or not some similar analysis is required to correlate the 9-mode composite emissions with transient cycle emissions is not known. Unfortunately, it is beyond the scope of this project to investigate this possibility.

In summary, the results of the analysis of this item showed that while there was a strong linear relationship between the 9-mode composite fuel consumption and emissions (in grams/minute) and most test cycles, the relationship was not good enough to predict driving cycle emissions or fuel consumption for most purposes. Reweighting the modes improves the correlation but gives a different set of weighting factors for each test cycle and emission. It was found that the reweighting technique requested was overly restrictive and that better correlations could probably be obtained using the alternate method suggested. The fuel consumption correlation can be greatly improved if the test cycle fuel consumption value for each truck

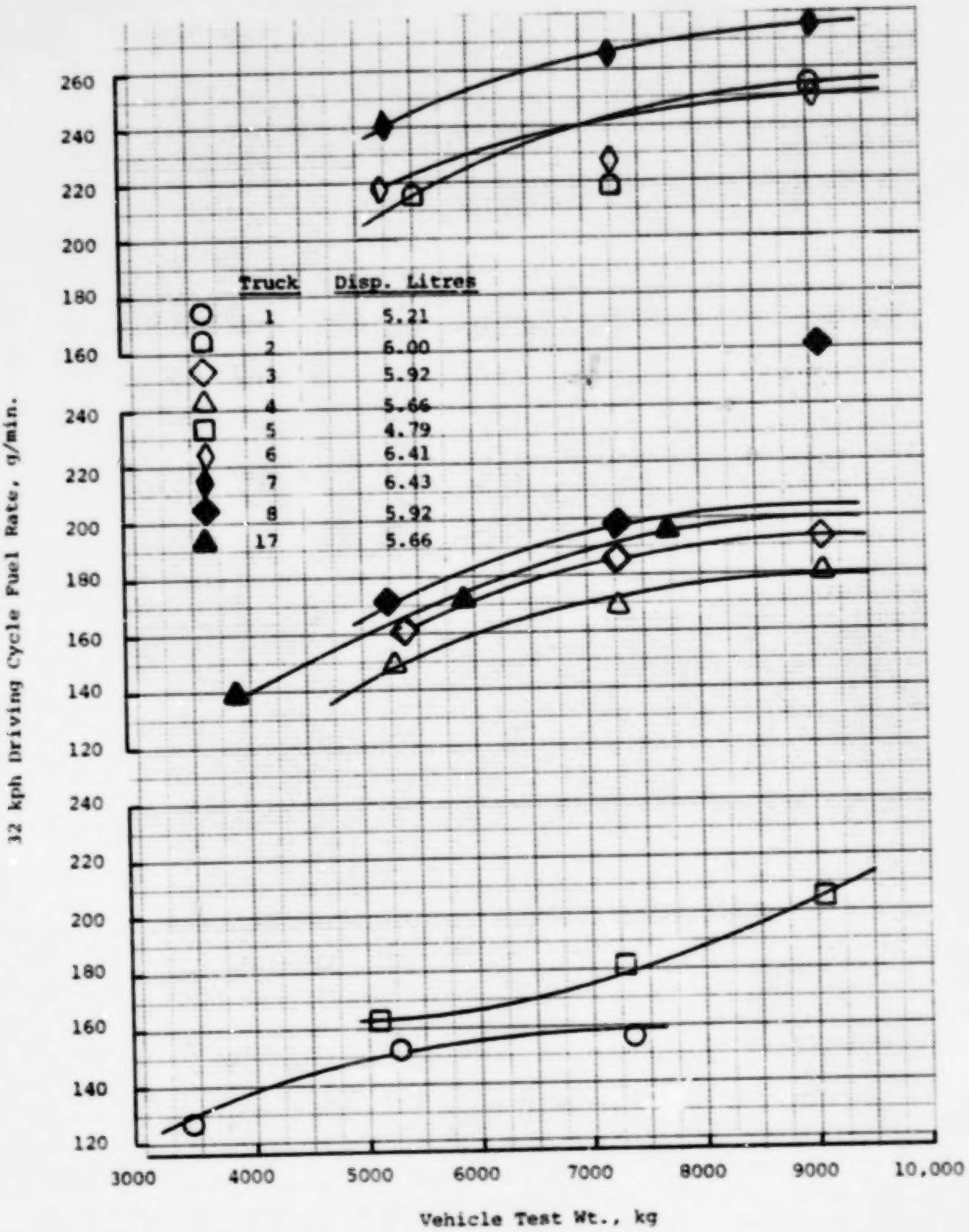


FIGURE 3. 32 KPH DRIVING CYCLE FUEL RATE VS. VEHICLE TEST WEIGHT FOR 9 SINGLE AXLE TRUCKS

Y = -66.98 + 0.012X
r^2= 0.834

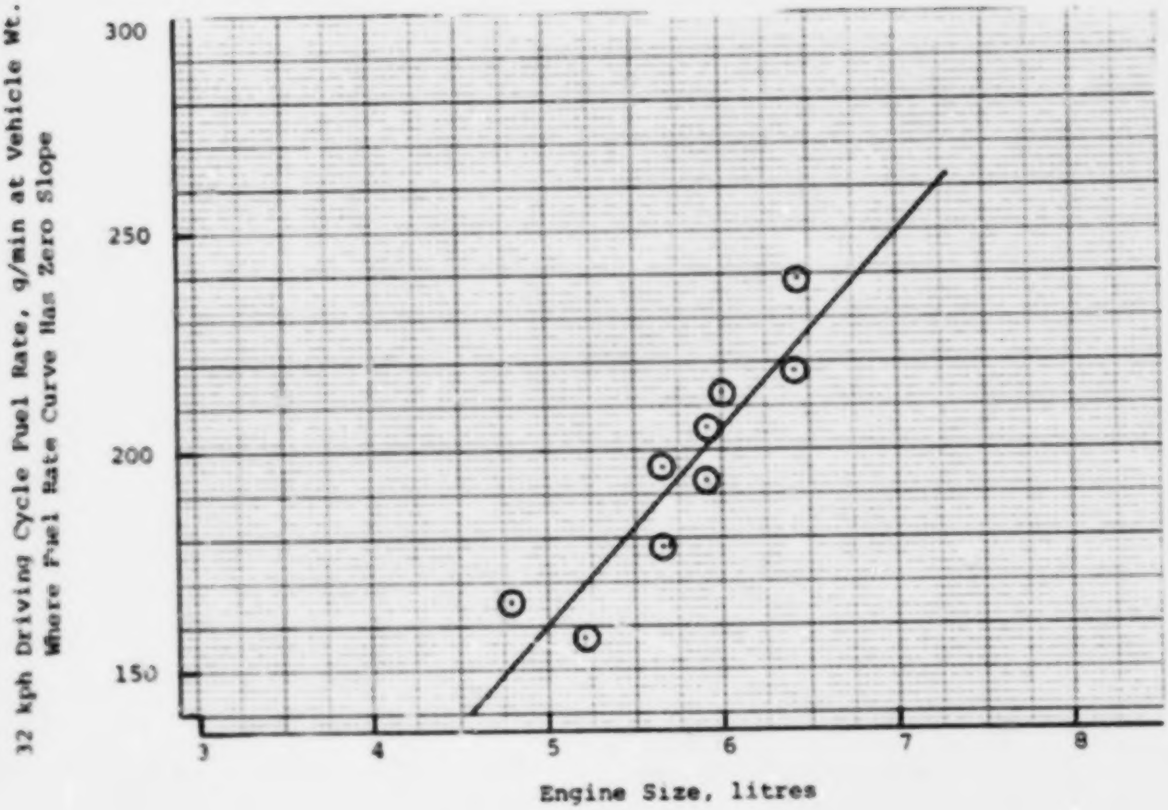


FIGURE 4. 32 KPH DRIVING CYCLE FUEL RATE AT ZERO SLOPE POINT VS. ENGINE SIZE FOR 9 SINGLE AXLE TRUCKS

TABLE 9. RESULTS OF SPECIAL REGRESSION ANALYSIS TO OPTIMIZE CORRELATION BETWEEN 9-MODE FUEL RATE AND 20 mph DRIVING CYCLE FUEL RATE FOR NINE SINGLE AXLE TRUCKS

Truck No.(1)	32 kph Driving Cycle Fuel Rate, g/min(2)	Reweighted 9-mode Fuel Rate, g/min
1	157.0	173.4
2	213.0	219.2
3	193.0	191.9
4	178.0	192.2
5	164.5	162.7
6	218.0	206.4
7	239.0	235.2
8	205.5	201.7
17	196.0	180.4

Mode	Manifold Vacuum In. Hg.	Weighting Factor
1	Idle	0.000
2	16	0.147
3	10	0.320
4	16	0.147
5	19	0.000
6	16	0.147
7	3	0.092
8	16	0.147
9	CT	0.000

---

(1) gasoline powered truck numbers from Contract 68-03-2147

(2) fuel rate at (vehicle weight, kg)/ $\left((\text{litres}-3.344)/.0164\right) = 60.2$

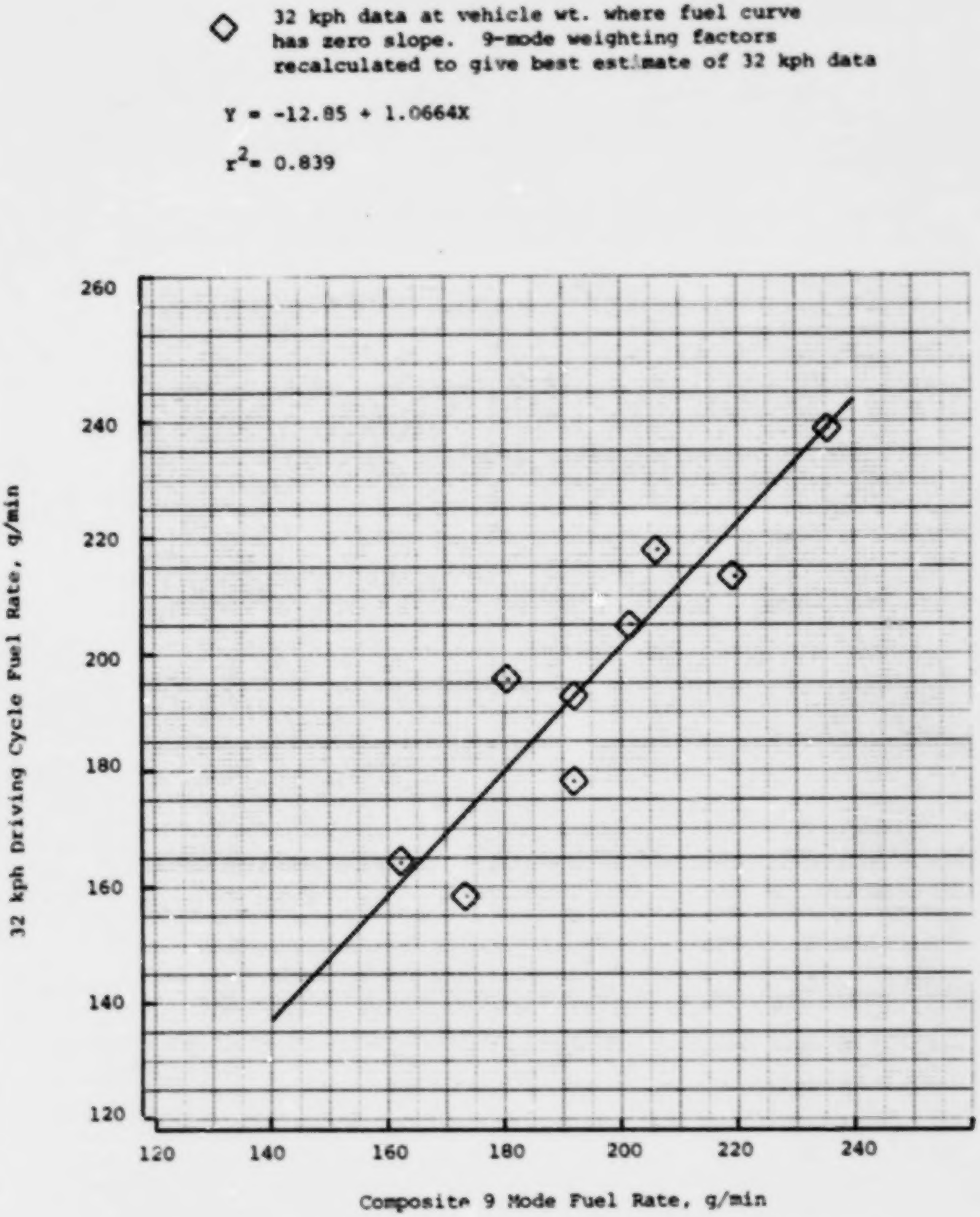


FIGURE 5. 32 KPH DRIVING CYCLE FUEL RATE VS. 9-MODE FUEL RATE FOR 9 SINGLE AXLE TRUCKS

is taken at the same value of a parameter that is a function of both vehicle weight and engine size. It is felt that this method would also improve the emissions correlations.

Thus, it is believed that this item has been investigated as far as it should be under the present allocation of effort, but that additional work should be done. This additional work would seem to have a good possibility of improving the correlation between 9-mode emissions and driving cycle emissions.

Item 3 - Will substituting a WOT mode for the 3" vacuum mode of the 9-mode cycle improve the correlation between the 9-mode cycle and other cycles?

The 9-mode FTP runs from the 18 gasoline trucks tested were reprocessed to give new weighted emissions and fuel rates using a WOT mode in place of the 3" vacuum mode. Table 10 shows the comparison of the two 9-mode tests for HC, CO, NO_x, and fuel rate for all 18 trucks. In general, replacing the 3" mode with a WOT mode resulted in little change in the weighted HC emission, an increase in CO, a decrease in NO_x, and a slight increase in fuel rate. These 9-mode results with the WOT mode were used to generate a new correlation matrix to determine if this method produces emission values with better correlations with any of the driving cycle emissions.

The variables showing high correlation are shown in Table 11. This list can be compared with the list using the regular 9-mode FTP given in the previous section. The composite CO emissions using the WOT mode correlate well with the 48 kph steady-state cycle for empty and half load, where they did not with the 3" mode. The composite NO_x emissions using the WOT mode no longer correlate with the 24 kph transient NO_x as they did using the 3" mode.

The relationships between the composite WOT 9-mode emissions and the driving cycle emissions of the same type are shown in the form of correlation coefficients in Table 12. The correlation coefficients using the WOT mode from Table 12 can be compared with those using the 3" vacuum mode from Table 4. The comparison shows no change in HC emission correlations using the WOT mode, changes but no trend for CO emissions, and worse correlations for NO_x and fuel when the WOT mode is used.

To determine if reweighting the WOT mode would improve the correlations, the special linear programming analysis was rerun using WOT in place of the 3" mode. A new series of weighting factors were obtained for the 60 driving cycle, load, and emission combinations. The weighting factors, which are the coefficients of the constrained regression equations, are included in Appendix B as Tables B-15 through B-18.

A correlation matrix was obtained for all three loads using the reweighted composite 9-mode results with the WOT mode substituted for the 3" mode. The correlation coefficients showing the relationship between the reweighted WOT 9-mode emissions and the various driving cycles are shown in Table 13. Comparing Table 12 and Table 13, it can be seen that reweighting

TABLE 10. COMPARISON OF 9-MODE COMPOSITE RESULTS FOR REGULAR 9-MODE FTP AND A 9-MODE TEST INCLUDING WIDE OPEN THROTTLE

Truck No.	9-mode HC g/min		9-mode CO g/min		9-mode NO_x g/min		9-mode fuel g/min	
	FTP	WOT	FTP	WOT	FTP	WOT	FTP	WOT
1	3.31	3.37	39.68	43.19	2.90	2.76	132.2	132.58
2	4.19	4.57	51.93	86.63	3.03	1.54	166.9	181.86
3	3.09	3.69	23.10	54.44	4.65	2.75	139.4	149.97
4	3.08	3.34	31.67	54.14	2.47	1.75	141.9	147.87
5	2.85	2.81	37.52	31.89	2.02	2.46	117.9	118.03
6	5.56	5.83	26.22	44.78	4.52	3.54	152.9	159.46
7	4.60	4.68	46.32	58.32	2.61	2.17	171.1	170.42
8	8.25	8.42	64.34	72.59	2.98	2.95	151.3	156.46
9	5.00	8.53	29.76	44.41	3.61	2.75	125.3	132.84
10	5.03	5.25	35.18	64.90	7.29	4.90	202.1	201.72
11	3.44	3.43	31.21	33.04	3.04	2.82	142.3	142.17
12	7.13	7.52	102.06	128.97	2.60	2.00	188.6	199.82
13	3.74	3.97	33.25	58.02	4.43	3.30	160.7	168.51
14	4.59	4.77	80.06	95.49	0.92	0.75	169.2	176.41
15	4.23	4.77	90.37	116.00	1.95	1.74	181.4	190.51
16	5.46	5.61	89.25	102.69	2.14	2.01	161.5	166.64
17	3.15	3.21	16.53	27.18	1.44	1.29	130.2	138.00
18	3.13	3.39	8.64	32.62	1.82	1.14	142.9	157.43

Note: rpm at 3" Hg mode varied from 2000 to 2100 while rpm at WOT was essentially 2000.

TABLE 11. RELATIONSHIPS BETWEEN MODAL AND CHASSIS DYNAMOMETER CYCLE EMISSIONS HAVING CORRELATION COEFFICIENTS ABOVE 0.9 FOR 9-MODE FTP COMPOSITE RESULTS WITH WOT REPLACING 3 INCH MODE

1. Composite 9-mode

Correlates with empty load

HC	CO	NO_x	Fuel Rate
20 mph sine HC	30 mph S/S CO		0 mph S/S Fuel
10 mph trans HC	30 mph sine CO		
15 mph trans HC			
20 mph trans HC			

2. Composite 9-mode

Correlates with half load

HC	CO	NO_x	Fuel Rate
20 mph sine HC	30 mph S/S CO		0 mph S/S Fuel
30 mph sine HC			
10 mph trans HC			
15 mph trans HC			
20 mph trans HC			

3. Composite 9-mode

Correlates with full load

HC	CO	NO_x	Fuel Rate
20 mph sine HC			0 mph S/S Fuel
30 mph sine HC			
10 mph trans HC			
15 mph trans HC			
20 mph trans HC			

TABLE 12. CORRELATION COEFFICIENTS BETWEEN RESULTS FROM WOT 9-MODE TESTS AND DRIVING CYCLE RESULTS FOR NINE SINGLE AXLE TRUCKS

Test	Empty Load				Half Load				Full Load			
Desc.	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel
00 SS	0.835	0.877	-0.581	0.949	0.715	0.875	-0.165	0.960	0.540	0.811	-0.795	0.914
05 SS	0.238	0.651	0.176	0.211	-0.126	0.734	0.286	0.385	0.139	0.766	0.203	0.441
10 SS	0.347	0.741	0.388	0.558	0.409	0.846	0.416	0.550	0.487	0.725	0.366	0.541
15 SS	0.028	0.817	0.260	0.662	-0.021	0.854	0.312	0.703	0.002	0.837	0.300	0.663
20 SS	0.419	0.827	0.597	0.704	0.469	0.789	0.554	0.678	0.653	0.819	0.650	0.715
30 SS	0.592	0.926	0.739	0.755	0.598	0.914	0.743	0.700	0.651	0.874	0.836	0.763
40 SS	0.478	0.800	0.813	0.884	0.360	0.676	0.794	0.849	0.432	0.659	0.853	0.854
55 SS	-0.276	0.358	0.343	0.553	0.155	-0.189	0.425	0.240	0.247	-0.532	0.513	0.137
20±5	0.940	0.876	0.630	0.639	0.916	0.765	0.470	0.693	0.936	0.293	0.373	0.605
30±5	0.831	0.953	0.628	0.521	0.935	0.720	0.579	0.627	0.952	0.460	0.306	0.348
40±2	0.446	0.896	0.860	0.561	0.409	0.705	0.882	0.633	0.406	0.327	0.704	0.403
05 Avg.	0.853	0.862	0.105	0.229	0.876	0.820	0.490	0.838	0.886	0.874	0.101	0.895
10 Avg.	0.946	0.800	0.193	0.740	0.930	0.662	0.202	0.752	0.964	0.836	0.179	0.799
15 Avg.	0.939	0.742	0.524	0.607	0.949	0.823	0.600	0.686	0.960	0.604	0.603	0.441
20 Avg.	0.931	0.479	0.178	0.634	0.939	0.271	0.338	0.492	0.964	0.558	0.313	0.494

TABLE 13. CORRELATION COEFFICIENTS BETWEEN REWEIGHTED WOT 9-MODE TESTS AND DRIVING CYCLE RESULTS FOR NINE SINGLE AXLE TRUCKS

Test Desc.	Empty Load				Half Load				Full Load			
	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel
20±5	0.947	0.947	0.749	0.856	0.940	0.882	0.508	0.870	0.927	0.468	0.430	0.771
30±5	0.928	0.984	0.704	0.748	0.947	0.798	0.626	0.829	0.957	0.649	0.504	0.578
10 Avg.	0.974	0.930	0.315	0.887	0.940	0.792	0.269	0.863	0.944	0.904	0.238	0.868
15 Avg.	0.977	0.845	0.618	0.779	0.969	0.930	0.717	0.813	0.979	0.787	0.768	0.527
20 Avg.	0.963	0.560	0.409	0.775	0.938	0.369	0.474	0.676	0.943	0.717	0.417	0.562

in general improves the correlation. To aid in comparing the various composite 9-mode results that have been calculated, the correlation coefficients for the non-steady state test cycles from each calculation method are shown in Table 14. Examination of this table reveals that for both the 9-mode tests with the 3" vacuum mode and the tests with the WOT, reweighting the modes improves the correlation. However, the reweighted WOT 9-mode correlations are not greatly different from the reweighted regular 9-mode correlations. Therefore, it must be concluded that substituting a WOT mode for the 3" vacuum mode of the 9-mode cycle will not improve the correlation between the 9-mode cycle and other cycles.

Item 4 - How does the percent change in fuel rate and emissions for various levels of control measured over the 9-mode cycle compare with the change in fuel rate and emissions over other cycles?

For this item, four levels of control were defined; pre-1970, 1970 to 1973, 1974 to 1975 Federal, and 1975 California. The pre-1970 truck emissions and fuel rate were used as the base levels. The percent changes were calculated for each emission type and fuel rate. These percent changes are shown in Tables 15 through 18. Keeping in mind that the sample size is small, some trend may be seen from the tables. As would be expected, the average 9-mode HC levels decrease with increasingly strict standards. This change is always reflected in the HC emissions for the driving cycles; but for the 1970 and 1974 standards, the HC reduction is not always seen in the steady-state and sinusoidal cycles. The percent change from the base HC level of the 16 kph and 32 kph driving cycle and the 89 kph steady-state cycle for the 1970 and 1974 standards show essentially no change from the one level of control to the next. All other cycles, with the exception of the idle cycle, show a decrease in HC emissions from 1970 (but not necessarily a decrease from pre-1970) as the standards become stricter.

The 9-mode CO emissions levels also decreased with increasingly stringent standards. Again, this change in always reflected in the driving cycles, but not always in the steady-state or sinusoidal cycles. All cycles show a decrease from 1970 (but again, not necessarily a decrease from pre-1970) as the standards become more stringent.

The 9-mode NO_x emissions increased from pre-1970 to the 1970 standard configuration and again from 1970 to the 1974 configuration. Only the NO_x levels from trucks built to 1975 California standards showed a decrease in 9-mode NO_x from pre-1970 levels. The driving cycles all showed an increase in NO_x over the levels from pre-1970 trucks, with the 1975 California trucks showing the smallest increase.

The 9-mode fuel rate decreased from pre-1970 to 1970 trucks, then increased for 1974-1975 Federal standard trucks. The 1975 California trucks show the largest 9-mode fuel rate decrease from the pre-1970 trucks. The driving cycles for all levels of control have lower fuel rates than the pre-1970 driving cycles.

It should be pointed out that the pre-1970 trucks were all at least six years old when tested and undoubtedly had experienced some performance deterioration. It is probable that both NO_x and fuel rate for the pre-1970

TABLE 14. CORRELATION COEFFICIENTS BETWEEN DRIVING CYCLE EMISSIONS AND 9-MODE EMISSIONS FOR SEVERAL VERSIONS OF THE 9-MODE TEST CYCLE

		Empty Load				Half Load				Full Load			
Emission Type	Test Desig-nation	9-Mode FTP	9-Mode FTP New W.F.	9-Mode w/WOT FTP W.F.	9-Mode w/WOT New W.F.	9-Mode FTP	9-Mode FTP New W.F.	9-Mode w/WOT FTP W.F.	9-Mode w/WOT New W.F.	9-Mode FTP	9-Mode FTP New W.F.	9-Mode w/WOT FTP W.F.	9-Mode w/WOT New W.F.
HC	20x5	0.934	0.942	0.940	0.947	0.915	0.940	0.916	0.940	0.937	0.927	0.936	0.927
	30x5	0.837	0.938	0.831	0.928	0.947	0.957	0.935	0.947	0.951	0.957	0.952	0.957
	40x2	0.403	-	0.446	-	0.378	-	0.409	-	0.377	-	0.406	-
	05 AVG.	0.860	-	0.853	-	0.884	-	0.876	-	0.890	-	0.886	-
	10 AVG.	0.953	0.975	0.946	0.974	0.939	0.939	0.930	0.940	0.966	0.944	0.964	0.944
	15 AVG.	0.933	0.975	0.939	0.977	0.948	0.966	0.949	0.969	0.960	0.975	0.960	0.979
	20 AVG.	0.934	0.960	0.931	0.963	0.941	0.932	0.939	0.938	0.964	0.939	0.964	0.943
CO	20x5	0.515	0.891	0.876	0.947	0.781	0.748	0.765	0.882	0.470	0.613	0.293	0.468
	30x5	0.805	0.976	0.953	0.984	0.808	0.844	0.720	0.798	0.737	0.692	0.460	0.649
	40x2	0.657	-	0.896	-	0.579	-	0.705	-	0.549	-	0.327	-
	05 AVG.	0.784	-	0.862	-	0.809	-	0.820	-	0.803	-	0.874	-
	10 AVG.	0.819	0.868	0.800	0.920	0.877	0.885	0.662	0.792	0.846	0.668	0.836	0.904
	15 AVG.	0.834	0.870	0.742	0.845	0.794	0.865	0.823	0.930	0.867	0.889	0.604	0.787
	20 AVG.	0.771	0.754	0.479	0.560	0.687	0.783	0.271	0.369	0.816	0.849	0.558	0.717
NO_x	20x5	0.832	0.884	0.630	0.749	0.822	0.878	0.470	0.508	0.845	0.907	0.373	0.430
	30x5	0.818	0.849	0.628	0.704	0.857	0.891	0.579	0.626	0.862	0.957	0.506	0.504
	40x2	0.527	-	0.860	-	0.604	-	0.882	-	0.673	-	0.704	-
	05 AVG.	0.564	-	0.105	-	0.760	-	0.490	-	0.683	-	0.101	-
	10 AVG.	0.802	0.980	0.193	0.315	0.787	0.983	0.202	0.269	0.757	0.903	0.179	0.238
	15 AVG.	0.941	0.958	0.524	0.618	0.886	0.921	0.600	0.717	0.851	0.922	0.603	0.768
	20 AVG.	0.762	0.869	0.178	0.409	0.829	0.920	0.338	0.474	0.861	0.938	0.313	0.417
Fuel Rate	20x5	0.712	0.856	0.639	0.856	0.754	0.870	0.639	0.870	0.673	0.783	0.605	0.771
	30x5	0.589	0.748	0.521	0.748	0.702	0.829	0.627	0.829	0.423	0.704	0.348	0.578
	40x2	0.685	-	0.561	-	0.741	-	0.633	-	0.487	-	0.403	-
	05 AVG.	0.865	-	0.229	-	0.866	-	0.838	-	0.899	-	0.895	-
	10 AVG.	0.803	0.887	0.740	0.887	0.814	0.863	0.752	0.863	0.829	0.869	0.799	0.868
	15 AVG.	0.656	0.776	0.607	0.779	0.743	0.855	0.686	0.813	0.500	0.603	0.441	0.527
	20 AVG.	0.695	0.785	0.634	0.775	0.610	0.735	0.492	0.676	0.547	0.675	0.494	0.562

TABLE 15. AVERAGE PERCENT CHANGE IN HYDROCARBONS FOR VARIOUS LEVELS OF EMISSION CONTROL (PRE-1970 BASE LEVEL)

	Level of Emission Control		
	1970-1973	1974-1975 Federal	1975 Calif.
9-Mode	-12.7	-20.0	-41.5
Steady State			
Idle	-75.8	-28.0	-96.1
15	-22.1	-38.5	-95.2
30	+61.5	+34.2	-90.3
55	-18.2	-18.8	-79.7
Sinusoidal			
20	+ 8.9	-16.9	-34.2
30	+ 9.9	-12.4	-60.0
40	+81.3	+61.7	-73.9
Driving			
10	-42.5	-41.9	-67.4
20	-29.2	-33.9	-62.5
Sample Size	4	8	2

TABLE 16. AVERAGE PERCENT OF CHANGE IN CARBON MONOXIDE FOR VARIOUS LEVELS OF EMISSION CONTROL (PRE-1970 BASE LEVEL)

	Level of Emission Control		
	1970-1973	1974-1975 Federal	1975 Calif.
9-Mode	-28.3	-36.1	-81.5
Steady State			
Idle	-21.4	-28.7	-87.4
15	+21.6	- 8.1	-87.9
30	+29.2	+10.4	-78.0
55	-38.3	-59.2	-65.7
Sinusoidal			
20	-18.0	-24.0	-46.0
30	+ 1.1	-26.9	-74.1
40	+32.9	+15.0	-63.7
Driving			
10	-14.4	-31.1	-60.7
20	-18.9	-29.0	-55.7
Sample Size	4	8	2

TABLE 17. AVERAGE PERCENT CHANGE IN OXIDES OF NITROGEN FOR VARIOUS LEVELS OF EMISSION CONTROL (PRE-1970 BASE LEVEL)

	Level of Emission Control		
	1970-1973	1974-1975 Federal	1975 Calif.
9-Mode	+71.3	+83.1	-20.0
Steady State			
Idle	+36.4	-18.2	+81.8
15	- 9.4	+64.9	+19.4
30	+49.5	+22.1	-31.5
55	+59.0	+128.7	+79.4
Sinusoidal			
20	+63.4	+83.8	+ 7.0
30	+37.0	+75.6	+27.8
40	+ 5.1	+19.8	-12.3
Driving			
10	+80.7	+149.8	+65.1
20	+45.4	+96.4	+44.7
Sample Size	4	8	2

TABLE 18. AVERAGE PERCENT CHANGE IN FUEL RATE FOR VARIOUS LEVELS OF EMISSION CONTROL (PRE-1970 BASE LEVEL)

	Level of Emission Control		
	1970-1973	1974-1975 Federal	1975 Calif.
9-Mode	- 2.3	+10.1	- 8.8
Steady State			
Idle	- 7.7	+ 3.9	-17.6
15	- 9.9	+22.8	+22.7
30	- 2.7	+14.8	+14.3
55	- 0.6	- 2.6	+ 8.3
Sinusoidal			
20	-13.0	+ 5.7	- 4.8
30	- 5.5	+ 9.2	+ 6.1
40	-12.5	+ 0.4	+ 1.6
Driving			
10	-15.7	- 2.2	- 8.0
20	-13.0	- 2.0	- 2.8
Sample Size	4	8	2

trucks were affected by this deterioration since both are at least partially a function of combustion efficiency. Thus, the baseline value for NO_x may be lower and the fuel rate higher than would have been seen is the pre-1970 trucks were tested when new.

Using the pre-1970 emissions as a base, the percent change in 9-mode emissions and the percent change in chassis dynamometer cycle emissions for each truck was used in a regression analysis. A separate regression was performed for each emission and cycle type. This then defined the relationship between percent change in 9-mode emissions and percent change in test cycle emissions for each emission and test cycle.

Table 19 shows the correlation coefficients and the linear equations from the regression analysis for the 1970 to 1973 level of emission control. Except for steady-state idle, the correlation coefficients indicate a strong linear relationship between changes in 9-mode emissions and fuel rate and changes in the other test cycle emissions and fuel rate. However, there were only four trucks in the 1970 to 1973 category. With only four data points, the correlation coefficients should be used with great care. An examination of the residuals from the equations reveals that there are large variations from the calculated relationships even for cycles with correlation coefficients above 0.9. The slopes of the lines indicate that the relationship between the 9-mode changes and other cycle changes are greatly different for each emission and test cycle combination. The intercept value, representing no change in the 9-mode emission from the average pre-1970 emission, is often unexplainable in terms of the physical considerations. For instance, several times this value is over 100 for both HC and CO. This means that for no change in 9-mode emissions, a change of over 100 percent could be expected in that particular emission and test cycle. It is not recommended that these equations be used to predict changes in driving cycle emissions from changes in 9-mode emission without further data.

The correlation coefficients for the relationship of the 9-mode and test cycle emission changes for the post-1974 emission control level are, in general, not high enough to indicate a good linear relationship (see Table 20). Thus, it appears that for the post-1974 emission levels, driving cycle emission changes from pre-1970 levels cannot be predicted from the 9-mode test. Since there were only two trucks tested which met the 1975 California emission standards, the regression analysis was not performed on those trucks.

Item 5 - How different are the rpm-time profiles and manifold vacuum-time profiles for a given transient cycle and load for different trucks?

It was decided that the best way to approach this problem was to obtain rpm-manifold vacuum matrices for the 18 gasoline trucks tested, similar to those produced by the CAPE-21 project. A special computer program was written to process the data tapes generated under Contract 68-03-2147 to obtain the desired matrices. The matrices for the 16 kph and 32 kph driving cycles for all 18 trucks are included in Appendix B as Tables B-19 through B-62. For the 16 kph transient cycle and the 32 kph transient cycle at half load on each truck, these matrices were condensed into time

TABLE 19. RELATIONSHIP BETWEEN CHANGE IN 9-MODE COMPOSITE EMISSIONS AND CHANGE IN DRIVING CYCLE EMISSIONS FOR 1970 TO 1973 LEVEL OF EMISSION CONTROL (AVERAGE PRE-1970 BASE LEVEL)

	HC			CO			NO_x			Fuel Rate		
Cycle	a	b	r	a	b	r	a	b	r	a	b	r
Idle SS	-74.76	0.08	0.454	-9.62	0.42	0.452	99.29	0.88	-0.857	-6.59	0.48	0.438
15 SS	4.27	2.07	0.963	109.29	3.11	0.958	-111.98	1.44	0.985	-6.38	1.50	0.995
30 SS	101.50	3.14	0.920	106.38	2.73	0.929	-27.08	1.08	0.941	1.24	1.70	0.945
55 SS	5.10	1.83	0.982	-4.61	1.19	0.906	-101.82	2.26	0.984	2.49	1.31	0.822
20 ± 5	21.77	1.01	0.901	18.23	1.28	0.976	-101.66	2.32	0.987	-11.00	0.86	0.814
30 ± 5	15.95	0.47	0.795	56.54	1.96	0.992	-74.05	1.56	0.947	-1.13	1.87	0.974
40 ± 2	119.10	2.97	0.965	104.22	2.52	0.997	-13.82	0.27	0.840	-8.79	1.58	0.962
10 Avg.	-35.05	0.59	0.888	9.55	0.85	0.987	-60.85	1.99	0.989	-13.05	1.14	0.936
20 Avg.	-17.11	0.95	0.991	6.92	0.92	0.997	-84.30	1.82	1.000	-10.42	1.10	0.945

---

form of equation: $y = a + bx$

where: y = percent change in driving cycle emissions or fuel rate
x = percent change in 9-mode emissions or fuel rate
r = correlation coefficient

sample size: Four 1970 to 1973 model gasoline trucks

TABLE 20. RELATIONSHIP BETWEEN CHANGE IN 9-MODE COMPOSITE EMISSIONS AND CHANGE IN DRIVING CYCLE EMISSIONS FOR 1974 LEVEL OF EMISSION CONTROL (AVERAGE PRE-1970 BASE LEVEL)

Cycle	HC			CO			NO_x			Fuel Rate		
	a	b	r	a	b	r	a	b	r	a	b	r
Idle SS	9.76	1.88	0.601	17.22	1.27	0.706	-57.73	0.48	0.672	-4.68	0.85	0.524
15 SS	-40.66	-0.11	0.053	85.39	2.59	0.934	9.94	0.66	0.644	7.12	1.55	0.513
30 SS	37.18	0.15	0.070	97.50	2.41	0.914	-20.67	0.52	0.755	8.31	0.64	0.347
55 SS	-29.51	-0.54	0.367	-60.05	-0.02	-0.024	73.99	0.66	0.807	-6.98	0.44	0.397
20 ± 5	5.96	1.14	0.600	-11.04	0.36	0.408	82.07	0.02	0.018	1.88	0.38	0.324
30 ± 5	27.45	1.99	0.712	1.56	0.79	0.856	52.80	0.28	0.314	2.50	0.67	0.458
40 ± 2	62.46	0.04	0.021	57.64	1.18	0.819	-38.54	0.70	0.895	-8.90	0.92	0.832
10 Avg.	-23.72	0.91	0.732	-9.07	0.61	0.707	128.82	0.25	0.319	-11.80	0.95	0.809
20 Avg.	-18.88	0.75	0.468	-6.70	0.62	0.526	77.90	0.22	0.369	-13.62	1.16	0.765

---

form of equation: $y = a + bx$

where: y = percent change in driving cycle
x = percent change in 9-mode
r = correlation coefficient

sample size: Eight 1974 or later gasoline trucks meeting Federal emission standards spent in various rpm intervals (regardless of vacuum) and time spent in various vacuum intervals (regardless of rpm). The cumulative percent times were then calculated for both the rpm and vacuum for each truck. The cumulative distributions for each truck were then compared with the distribution of each of the other trucks, one at a time, using the Kolmogorov-Smirnov (KS)(22) test.

Table 21 lists truck pairs which showed no significant difference (at the 0.05 level) in cumulative distributions. As an aid to understanding this table, a description of the gasoline trucks is included in Appendix A. It is interesting to note, from Table 21, that for the 32 kph transient cycle, only two pairs of trucks (Nos. 2 and 6 and Nos. 3 and 12) had cumulative vacuum distributions that were not significantly different. This excludes the repeat and alternate runs of Trucks 17 and 18 which, of course, should agree with each other.

Trucks 2 and 6 are both single axle trucks, so it is not surprising that they would have similar vacuum distributions. In fact, it is surprising that only two of the single unit trucks and none of the tractor-trailers have vacuum distributions that agree with each other. It is interesting that Trucks 3 and 12 had similar vacuum distributions despite the fact that Truck 3 is a single unit truck and Truck 12 is a tractor-trailer which has a slightly different 32 kph transient cycle.

Eight pairs of trucks have rpm distributions for the 32 kph cycle which are not significantly different from each other, not counting repeat and alternate runs of Trucks 17 and 18. The two trucks within a similar pair are both from the same truck type (single unit or tractor-trailer) in all cases. While more trucks have rpm distributions than vacuum distributions that agree, at the most, only four of the nine single unit trucks have rpm distribution that agree with each other and only two of the tractor-trailers have rpm distributions that agree. It is again interesting that two different type trucks, Truck 13 (a tractor-trailer) and Truck 15 (a single unit, 3-axle truck), have similar rpm distributions despite the fact that the two 32 kph driving cycles are somewhat different.

The 16 kph driving cycle data show more pairs of trucks with vacuum and rpm distributions that are not significantly different than the 32 kph driving cycle. In many of the 16 kph pairs, both trucks are not of the same type. Of all the distributions, only the rpm distributions for Truck pair 3 and 6 and Truck pair 5 and 6 show agreement for both the 32 kph and 16 kph transient cycles.

Since differences in rpm and manifold vacuum for trucks operating over the same driving cycle have important implications in the development of possible new certification cycles, it was decided to compare the matrices on a cell-by-cell basis. To do this, data were written in vector form (instead of matrix form) by extending each vacuum row by the next lower one. For example, the data had the following form, y_{jk}, where "k" referred to rpm and was the fastest moving index and "j" referred to vacuum and was the second fastest moving index.

The extended vector for each truck was compared with the vector of

TABLE 21. GASOLINE-POWERED TRUCK PAIRS SHOWING SIMILAR MANIFOLD VACUUM AND ENGINE RPM DISTRIBUTIONS USING KOLMOGOROV-SMIRNOV TEST

I. Truck pairs with similar distribution (at 0.05 level) of time at various manifold vacuum levels for half load, 32 kph transient driving cycle.

(2, 6)
(3, 12)
(17, 17R)
(17, 17A)
(18, 18R)
(18, 18A)
(18A, 18R)*

II. Truck pairs with similar distribution (at 0.05 level) of time in various engine rpm intervals for half load, 32 pkh transient driving cycle.

(2, 3)
(3, 4)
(3, 6)
(4, 6)
(5, 8)
(13, 15)
(13, 18R)
(15, 18R)

III. Truck pairs with similar distribution (at 0.05 level) of time at various manifold vacuum levels for half load, 16 kph transient driving cycle.

(2, 7)
(2, 13)
(7, 13)
(10, 14)
(15, 17)
(15, 17A)
(17, 17A)
(18, 18R)

IV. Truck pairs with similar distribution (at 0.05 level) of time in various engine rpm intervals for half load, 16 kph transient driving cycle.

(3, 6)
(5, 8)
(5, 17R)
(6, 11)
(7, 11)
(7, 14)
(7, 16)
(7, 18)
(7, 18R)
(7, 18A)
(8, 12)
(11, 14)
(11, 16)
(11, 18)
(14, 16)
(14, 18)
(14, 18R)
(16, 18)
(16, 18R)
(17, 17A)
(18, 18R)
(18, 18A)

*A is alternate cycle
R is repeat test using original cycle

each other truck, one at a time, using the KS test statistic. This was done for both the 16 kph and 32 kph average speed driving cycles. All trucks differed significantly (at the 0.05 level) except for 7 and 13, 17 and 17R, and 18 and 18R for 16 kph. In 32 kph, all trucks except Trucks 17 and 17R, 17 and 17A, 17R and 17A, and 18 and 18A differed significantly. It can be concluded that in the majority of the cases, the trucks did not have similar distributions of percent time spent at various combinations of rpm and vacuum.

Item 6 - For an average speed of 32 kph, how well do sinusoidal fuel consumption and emissions approximate a fully-transient cycle fuel consumption and emissions? Above 32 kph, how well does a steady-state approximate a sinusoidal cycle?

The approach to this item was to perform a linear regression on all gasoline trucks to determine if there was a relationship for fuel consumption and emissions between the 32 kph sinusoidal cycle and the 32 kph transient cycle; the 64 kph sinusoidal and the 64 kph steady-state. The 48 kph sinusoidal cycle was also compared to the 48 kph steady-state. A linear regression was performed on the half load results for each emission and fuel consumption. The regression coefficients and correlation coefficient for each regression are shown in Table 22. The scatter plots are shown in Figures 6 through 11.

As would be expected, there is a decreasing correlation for all variables of any two cycles as the cycles became less alike. Fuel consumption in grams per minute correlates better than emissions for all three cases. The most obvious use for this data is to determine if sinusoid excursions about a given speed could be used to predict emissions and fuel consumption for transient cycles. The answer is a matter of judgment and depends on how accurately the transient emissions are desired. In general, the correlation coefficients indicate that except for the 64 kph correlation, the correlations are not sufficient for most purposes and their use is not recommended.

It should also be pointed out that the correlation shown between the 32 kph sinusoidal cycle and the 32 kph average speed transient cycle is for one specific transient cycle. The correlation between the sinusoidal and transient cycle for other transient cycles with different characteristics could be different.

Item 7 - Does load setting have the same effect on fuel rate and emissions for each average speed? Do fuel rate and emissions vary with average speed? Do fuel rate and emissions vary with different cycles at the same average speed?

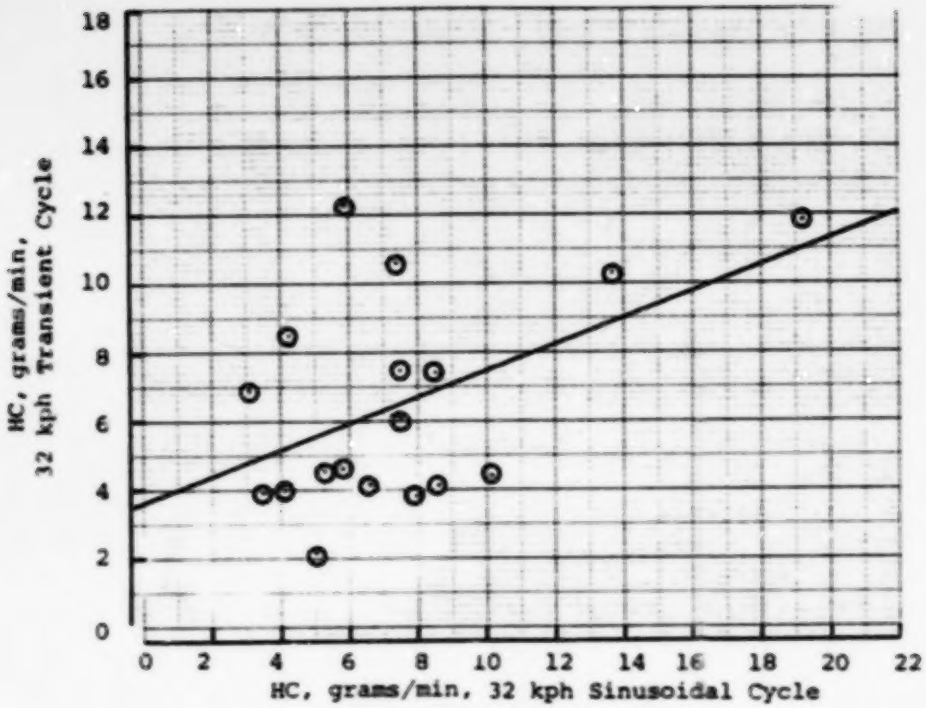
These three questions were included as one item since they can all be answered by performing a multiple regression analysis using load, speed, and speed times load as the variables for each emission type and each test cycle type for each truck.

This analysis was performed using data from each of the 18 trucks, with separate regressions for each of the 4 emissions and each of the 3 cycle

TABLE 22. LINEAR REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS OF FUEL CONSUMPTION AND EMISSIONS FOR VARIOUS DRIVING SCHEDULES

Form of equation: $y = a + bx$

Driving Cycles (Half Load)	a	b	Correlation Coefficient
I. 32 kph, sine (± 8 kph) vs transient			
HC	3.659	0.383	0.478
CO	43.279	1.182	0.567
NO_x	2.113	0.307	0.499
Fuel Consumption	48.742	0.902	0.662
II. 48 kph, sine (± 8 kph) vs steady state			
HC	1.083	0.166	0.399
CO	-3.182	0.827	0.847
NO_x	1.331	0.460	0.646
Fuel Consumption	-5.581	1.003	0.939
III. 64 kph, sine (± 3 kph) vs steady state			
HC	-0.252	+0.995	0.941
CO	-3.138	+0.939	0.901
NO_x	0.615	+0.940	0.923
Fuel Consumption	15.526	+0.947	0.973



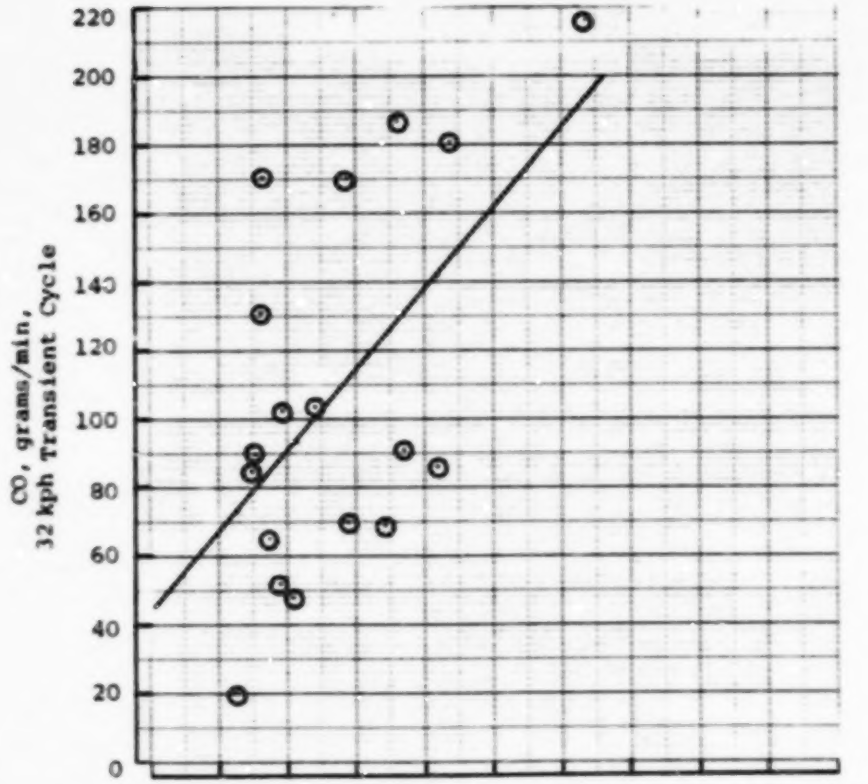
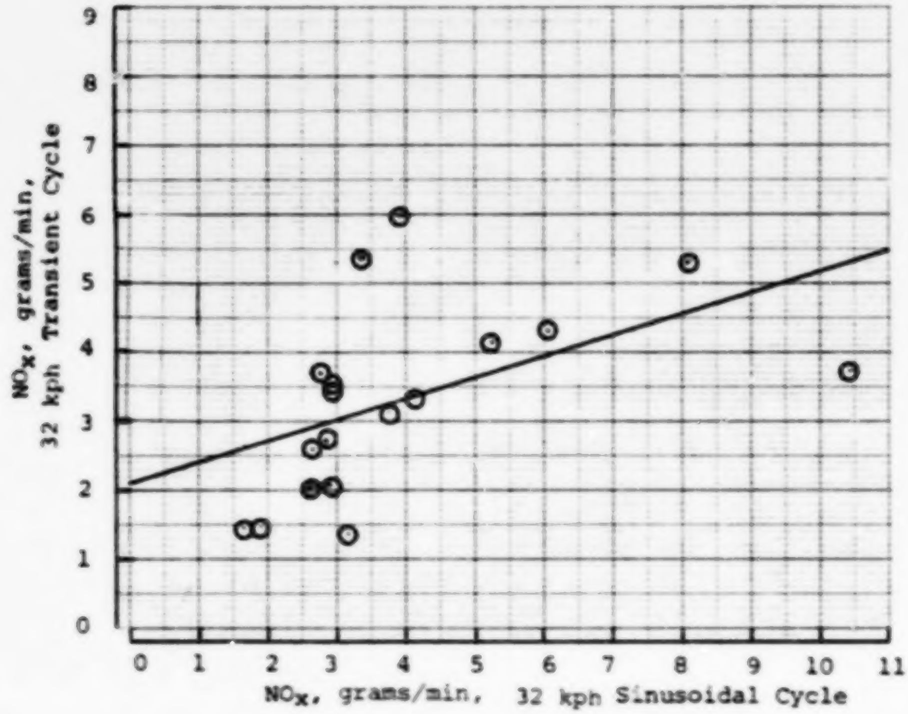


FIGURE 6. TRANSIENT 32 KPH HC AND CO EMISSIONS AS A FUNCTION OF 32 KPH SINUSOIDAL HC AND CO EMISSIONS



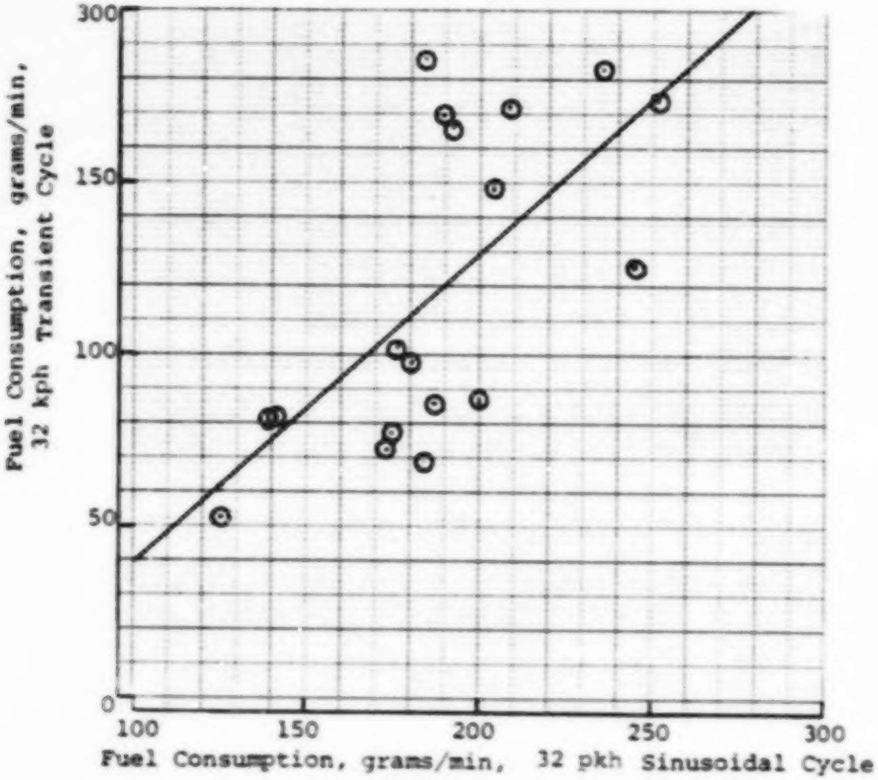
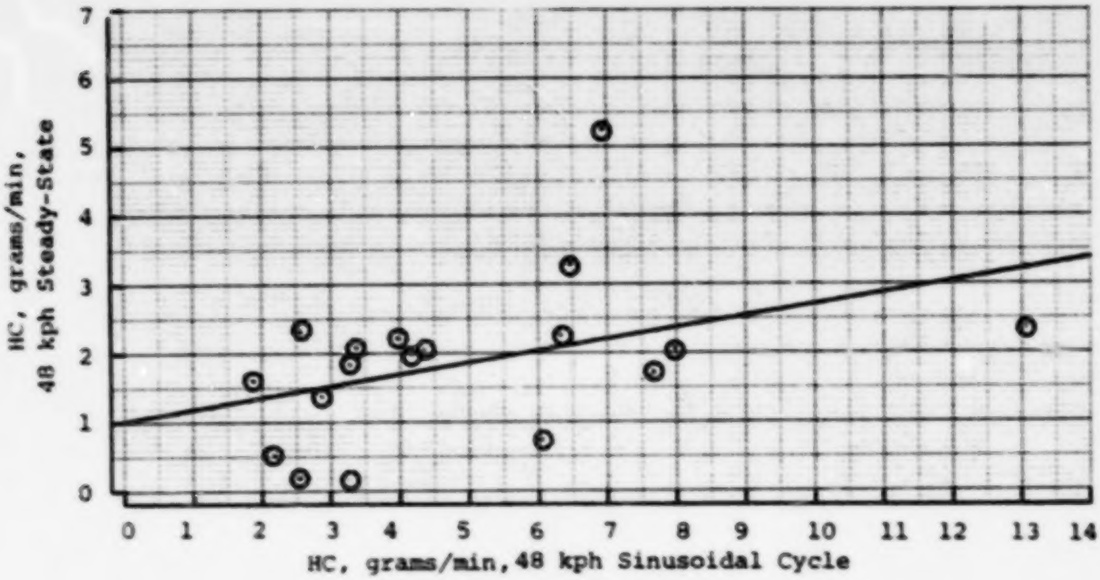


FIGURE 7. TRANSIENT 32 KPH NOx EMISSIONS AND FUEL RATE AS A FUNCTION OF 32 KPH SINUSOIDAL NOx EMISSIONS AND FUEL RATE



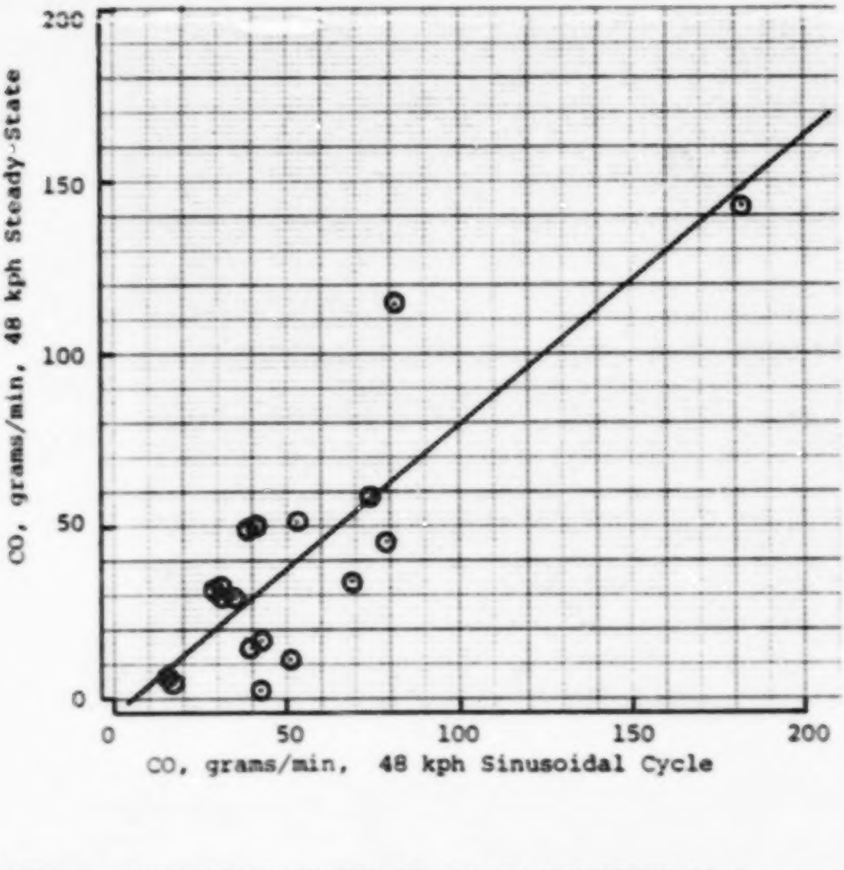
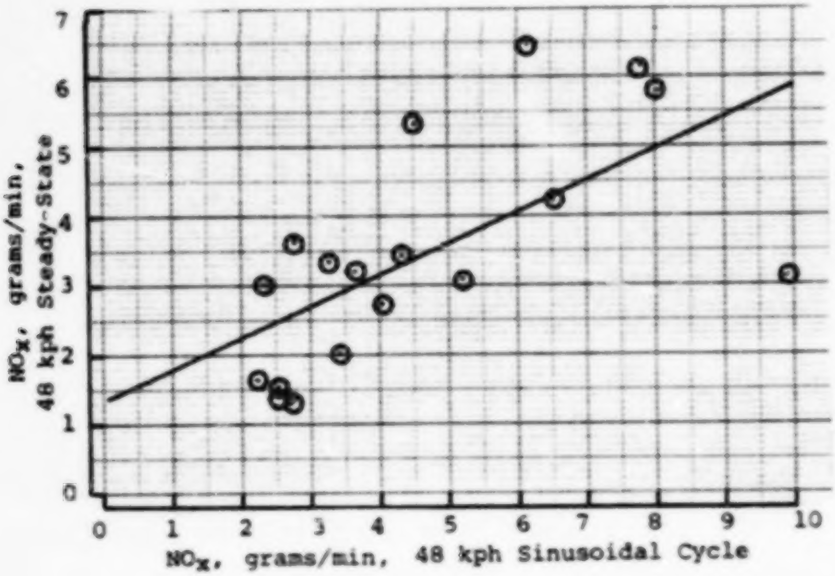


FIGURE 8. SINUSOIDAL 48 KPH HC AND CO EMISSIONS AS A FUNCTION OF 48 KPH STEADY-STATE HC AND CO EMISSIONS



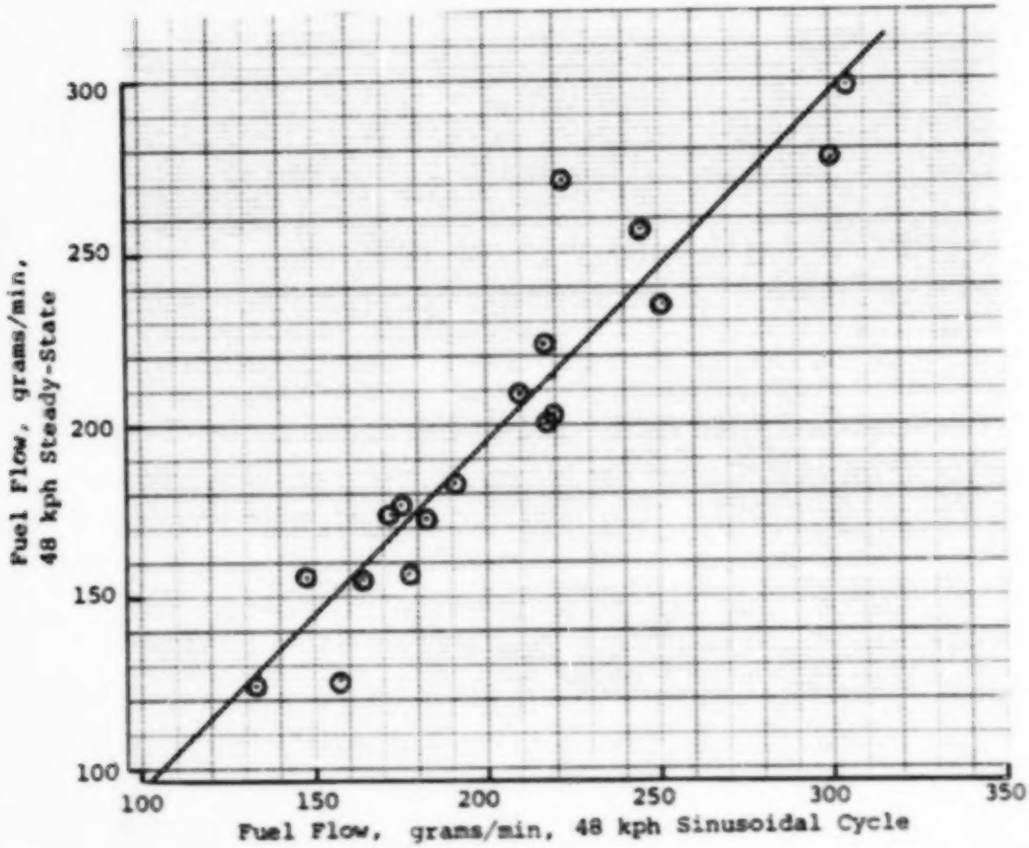


FIGURE 9. SINUSOIDAL 48 KPH NO$_x$ EMISSIONS AND FUEL RATE AS A FUNCTION OF 48 KPH STEADY-STATE NO$_x$ EMISSIONS AND FUEL RATE

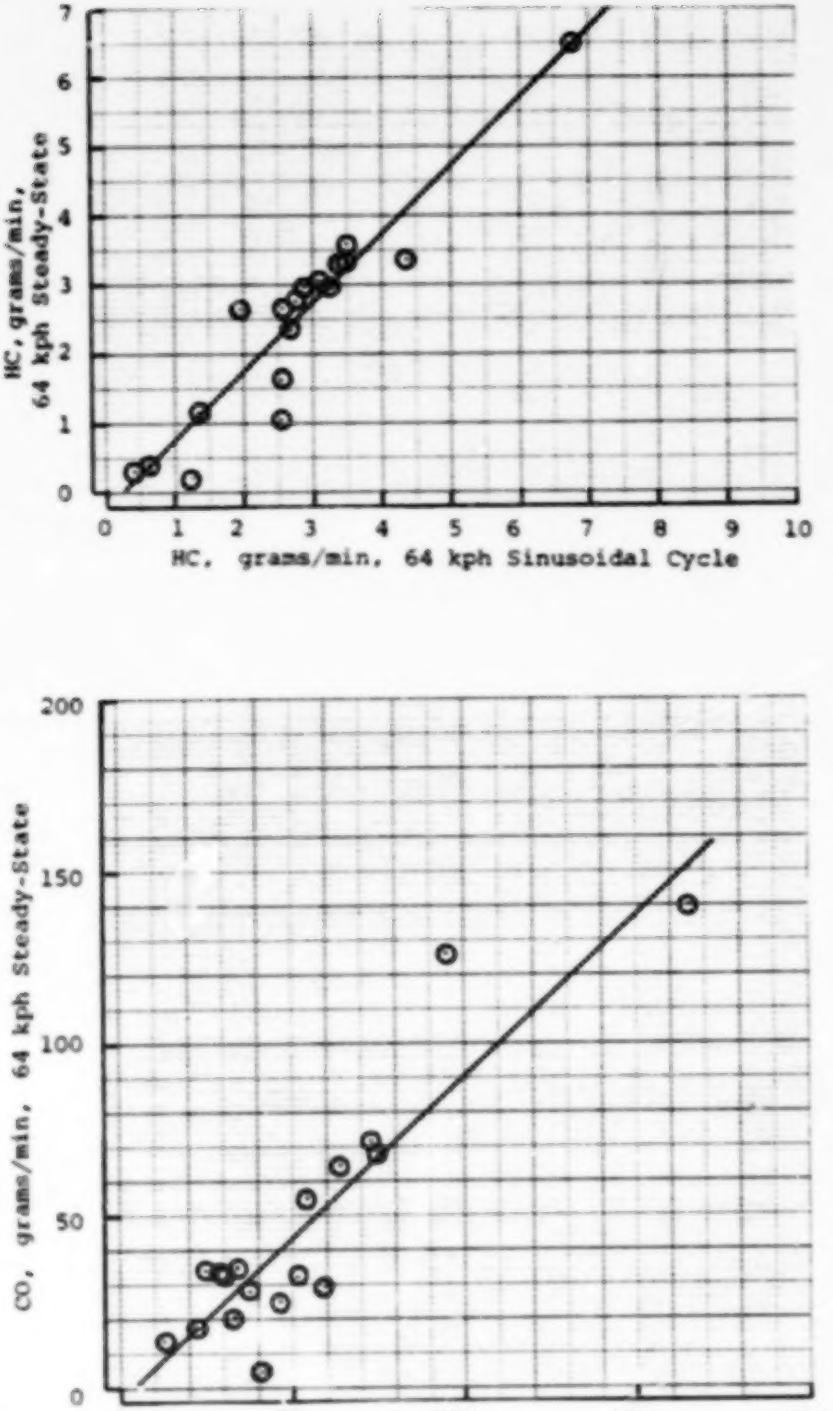


FIGURE 10. SINUSOIDAL 64 KPH HC AND CO EMISSIONS AS A FUNCTION OF 64 KPH STEADY-STATE HC AND CO EMISSIONS

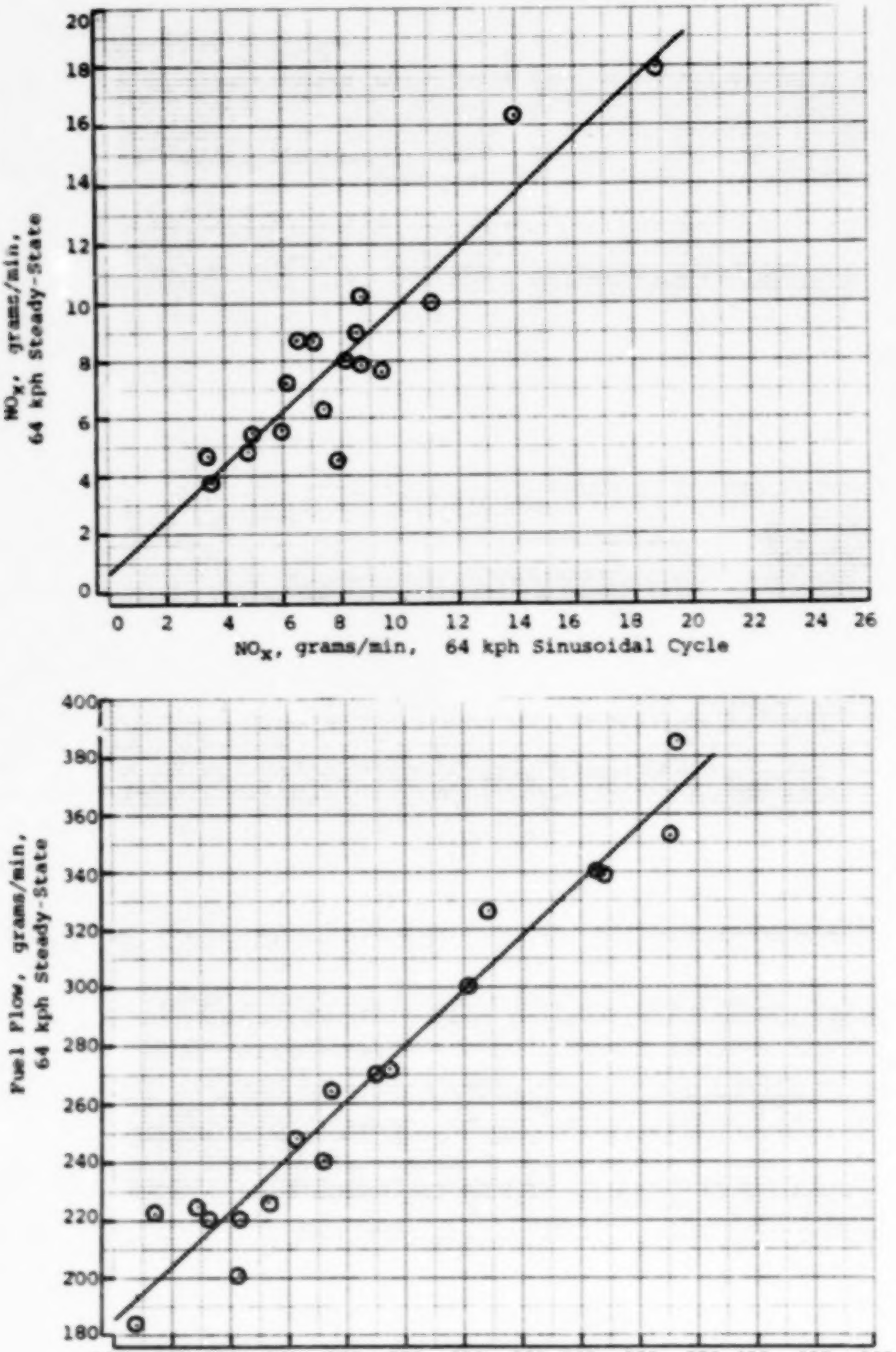


FIGURE 11. SINUSOIDAL 64 KPH NO$_X$ EMISSIONS AND FUEL RATE AS A FUNCTION OF 64 KPH STEADY-STATE NO$_X$ EMISSIONS AND FUEL RATE

types, resulting in 216 equations. The coefficients for these equations are shown in Appendix B, Tables B-63 through B-74 together with indications of "goodness of fit" of each equation. It should be pointed out that for these equations, load was kg/1000 and speed in kph/8. This was done to obtain variables of the same order of magnitude, so that the load times speed term would not be unduly influenced by large differences in magnitude of the values. The form of the equation calculated is shown below:

$$\text{emission} = \text{constant} + b_1\ (\text{load}) + b_2\ (\text{speed}) + b_3\ (\text{load} \times \text{speed}).$$

To answer the first question, "Does load have the same effect on emissions for each average speed?" we can look at how load varies at a constant speed. Since speed is a constant, the equation reduces to:

$$\text{emission} = \text{new constant} + (b_1 + b_3\ \times \text{speed})\ \text{load}$$

where new constant = constant + b_2 x speed.

If load had the same effect on emissions for each average speed, the load coefficient in the reduced equation ($b_1 + b_3 \times$ speed) would be the same for each speed. In other words, the emission change with load would be independent of speed. As can be seen from the reduced equation, as long as the coefficient for the load times speed term (b_3) is not zero, this will not be the case. Thus, it can be said that in general, speed does alter the effect of load on emissions. The questions are then, "Is this a significant effect?" More importantly, "Is load even a significant variable at a given speed?"

To answer these questions, the significance of each of the coefficients was examined using an F statistic. The significant coefficients are marked in Appendix B as Tables B-63 through B-74. Examining the tables, load at a given speed, coefficient b_1, appears to be a significant variable for HC on 33 percent of the trucks for the sinusoidal tests and 6 percent of the trucks on both the transient cycle and steady-state tests. The load times speed coefficient b_3 is significant for 6 percent of the trucks on the sinusoidal cycle and 11 percent of the trucks each on the driving and steady-state cycles. Six percent of the trucks in each of the test cycle types had HC emissions that are significantly affected both by load and by load times speed. Thus, it appears that HC emissions from some trucks were significantly influenced by load setting at a given speed, but only for one truck on the steady-state and one truck on the driving cycle did speed significantly alter the effect of load on HC emissions.

The same type of analysis can be done for CO, NO_x, and fuel consumption. In general, except for CO emitted during the sinusoidal cycle, load at a given speed was not significant for CO, NO_x, or fuel. It should be noted that this does not mean that these emissions and fuel consumption are not, at least partially, functions of load, it means that either load alone does not account for all of the change seen at constant speed, or that the data are unable to show it.

To summarize, load is generally not statistically significant in its influence on emissions or fuel consumption at a given speed. For approximately three fourths of the trucks relationships of emissions and fuel consumption with load do not change significantly from one speed to another.

The next question was: Do fuel rate and emissions vary with average speed? To answer this question, load is held constant and the general equation reduces to:

$$\text{emissions} = \text{new constant} + \left(b_2 + (b_3 \times \text{load})\right) \text{ speed}$$

where new constant = constant + b_1 (load).

If the reduced coefficient, $b_2 + (b_3 \times \text{load})$, is significantly different from zero for the test cycle and emissions (of fuel consumption) under consideration, then there is a variation with speed.

The different test cycles were examined individually beginning with the transient driving cycles. For HC, speed at a given load, coefficient b_3, is a significant variable for 28 percent of trucks and load times speed, coefficient b_3,is significant for 11 percent of the trucks. For CO, speed at a given load is significant for 22 percent of the trucks and load times speed is significant for 28 percent of the trucks. For NO_x, speed at a given load is significant for 100 percent of the trucks and load times speed is significant for 28 percent of the trucks. For fuel consumption, speed at a given load is significant for 56 percent of the trucks and load times speed for 28 percent of the trucks.

The sinusoidal test cycles showed a few trucks where speed at a given load is a significant variable. This is probably because there are only three speeds, 32, 48, and 64 kph which are generally in the mid-power range of the engine and so require little change in engine operating condition. For HC, speed was a significant variable for 6 percent (one truck) of the trucks and load times speed for 6 percent (one truck) of the trucks. For CO, speed was significant for 6 percent of the trucks and load times speed was significant for 22 percent of the trucks. For NO_x, speed was significant for 6 percent of the trucks and load times speed for none of the trucks. For fuel consumption, speed was significant for 17 percent of the trucks and load times speed for none of the trucks.

The steady-state test cycles showed speed at a given load as a significant variable more often than the sinusoidal test cycles. For HC, speed is a significant variable for 28 percent of the trucks and load times speed for 11 percent of the trucks. For CO, speed is significant for 22 percent of the trucks and load times speed for 28 percent of the trucks. For NO_x, speed is significant for 56 percent of the trucks and load times speed for none of the trucks. For fuel consumption, speed is significant for 66 percent of the trucks and load times speed for 17 percent of the trucks.

To summarize, except for the sinusoidal cycle, speed has a statistically significant influence on HC and CO emissions at a given load for approximately one quarter of the trucks. Further, speed has a statistically significant influence on NO_x at a given load for 56 percent to 100 percent of the trucks, excluding the sinusoidal tests. Finally, speed has a statistically significant influence on fuel consumption at a given load from a 56 to 66 percent of the trucks, again excluding the sinusoidal tests.

The last question of this item is: Do fuel rate and emissions vary with different cycles at the same average speed? For emissions and fuel consumption to be the same at a given speed and load for each of three cycles, the coefficients of the equations for that emission would have to be the same for each cycle. An examination of Appendix B Tables B-63 through B-74 indicates that this is generally not the case. However, it is felt that a more direct way to answer this question is to directly compare the emissions and fuel rate for the same average speed and load conditions on each truck.

These comparisons are shown in Tables 23 through 26 for HC, CO, NO_x, and fuel rate, respectively. Since the test-to-test variability for these cycles has not been defined, it is difficult to determine at what level the cycle-to-cycle differences at the same speed are significant. However, some insight may be gained by examining the average values of all trucks for each cycle at a given speed.

For HC emissions, there appears to be little difference between the 64 kph steady-state and sinusoidal (±4 kph) emissions and between the 32 kph sinusoidal and transient emissions. For the other speeds, the average HC emissions for the steady-state cycle are appreciably lower than the corresponding transient or sinusoidal cycle.

The average CO emissions from the steady-state cycles are appreciably lower than the corresponding transient or sinusoidal cycle for all speeds except 64 kph. The average CO emissions from the 64 kph steady-state and sinusoidal cycles are essentially the same.

There is apparently little difference in NO_x emissions between the 8 kph steady-state and transient cycles and between the 64 kph steady-state and sinusoidal cycles. At other speeds, the average NO_x emissions from the steady-state cycles are lower than the NO_x emissions from the corresponding transient or sinusoidal cycles.

There is little difference in average fuel rate values from the 48 kph steady-state and sinusoidal cycles and from the 64 kph steady-state and sinusoidal cycles. The fuel rates for corresponding cycles at other speeds are not equal.

To summarize, for all of the emissions, some of the test cycles gave equivalent results at some of the tested speeds. The 64 kph steady-state and sinusoidal cycles always had equivalent average emissions (and fuel consumption). It should be emphasized that individual truck emissions (and fuel consumption) varied from the relationships found in the average data and these average trends should not be used to define relationships for an individual vehicle.

Item 8 - How does the SARR data compare with other 32 kph transient driving cycles?

To answer this question, the average percent time frequency distributions of vehicle speed and engine rpm from the San Antonio Road Route (SARR) were compared with the same data from the 18 gasoline trucks from Contract 68-03-2147. The time-in-manifold vacuum was not compared since it conveys little information without a knowledge of the corresponding engine speeds. First, the percent time in various vehicle speeds for the

TABLE 23. COMPARISON OF GASOLINE TRUCK HC EMISSIONS IN GRAMS/MINUTE FROM DIFFERENT DRIVING CYCLES AT THE SAME AVERAGE SPEED
(HALF LOAD DATA)

Avg. Speed, kph	8		16		24		32			48		64	
Cycle	SS	Trans	SS	Trans	SS	Trans	SS	Sine	Trans	SS	Sine	SS	Sine
Truck 1	0.15	1.45	0.12	3.74	0.40	2.71	0.35	7.97	3.81	0.78	6.07	1.02	2.52
2	0.82	2.00	0.96	3.51	1.07	3.11	1.16	8.59	4.10	1.99	4.14	3.06	3.09
3	0.49	2.09	0.73	4.13	0.75	3.27	1.36	6.59	4.19	2.02	4.34	2.67	1.97
4	6.33	3.35	0.76	3.34	0.75	3.45	0.84	4.17	4.03	1.83	3.27	3.31	3.33
5	2.64	3.11	2.04	4.20	4.30	2.82	2.08	3.56	3.90	1.47	2.89	1.19	1.31
6	0.77	5.77	0.72	7.11	0.66	5.97	1.15	7.47	6.05	2.09	7.98	2.97	2.88
7	0.86	2.11	0.88	3.98	1.08	3.40	1.30	10.14	4.52	1.75	7.67	1.65	2.52
8	1.76	8.85	1.87	12.84	1.81	9.92	2.05	19.20	11.82	2.31	13.06	2.37	2.69
9	1.44	5.11	1.22	3.99	1.32	5.44	1.51	7.57	7.51	2.24	6.31	2.99	3.22
10	1.57	4.04	1.28	6.82	1.39	9.25	1.55	7.46	10.60	2.22	3.93	3.39	4.36
11	0.31	2.49	1.13	3.67	1.48	4.33	1.65	5.24	4.56	2.36	2.52	3.35	3.47
12	3.38	4.83	3.97	7.94	3.71	9.79	4.02	13.72	10.29	5.28	6.98	6.51	6.74
13	0.53	3.05	0.50	4.66	0.72	6.54	0.95	3.10	6.90	1.61	1.86	2.66	2.63
14	0.77	5.96	0.73	9.58	0.83	11.01	0.86	5.90	12.28	0.52	2.17	0.21	1.24
15	1.66	5.05	2.01	6.93	2.61	8.98	2.60	8.55	7.43	3.30	6.42	3.60	3.49
16	0.93	5.89	1.18	7.84	0.99	9.28	0.99	4.25	8.43	2.09	3.44	2.78	2.73
17	0.12	0.86	0.09	2.16	0.09	1.55	0.10	5.03	2.18	0.18	3.24	0.40	0.62
18	0.11	2.14	0.09	3.45	0.10	4.72	0.10	5.88	4.65	0.13	1.07	0.30	0.42
Avg.	1.37	3.79	1.13	5.55	1.34	5.86	1.37	7.47	6.51	1.90	4.85	2.47	2.74
Min.	0.11	0.86	0.09	2.16	0.09	1.55	0.10	3.10	2.18	0.13	1.07	0.21	0.42
Max.	6.33	8.85	3.97	12.84	4.30	11.01	4.02	19.20	12.28	5.28	13.06	6.51	6.74
Coeff. of Var.	111%	54%	82%	49%	86%	52%	68%	52%	47%	62%	60%	62%	53%

TABLE 24. COMPARISON OF GASOLINE TRUCK CO EMISSIONS IN GRAMS/MINUTE FROM DIFFERENT DRIVING CYCLES AT THE SAME AVERAGE SPEED
(HALF LOAD DATA)

Avg. Speed, kph	8		16		24		32			48		64	
Cycle	SS	Trans	SS	Trans	SS	Trans	SS	Sine	Trans	SS	Sine	SS	Sine
Truck 1	1.7	19.5	2.3	53.5	2.3	41.0	2.6	31.1	90.2	3.1	42.4	4.7	41.8
2	35.3	43.8	41.1	61.2	45.0	57.6	36.5	69.4	68.7	58.8	74.4	68.4	74.3
3	6.9	32.0	13.9	50.8	11.3	50.6	19.1	34.8	64.6	29.4	31.1	34.5	24.8
4	2.6	11.8	8.6	38.7	7.8	32.1	8.7	57.7	70.1	17.5	42.8	32.4	51.8
5	16.1	15.5	14.1	55.2	14.8	32.3	14.7	39.4	102.5	11.7	51.3	27.8	37.5
6	7.8	11.3	10.1	30.4	6.6	27.9	17.7	42.4	48.2	29.3	35.2	32.7	28.1
7	23.3	48.6	21.2	67.0	23.5	60.3	32.6	83.5	85.9	34.1	68.9	25.7	46.4
8	50.8	50.0	47.8	74.2	44.0	61.8	52.5	74.4	91.1	51.7	53.1	21.7	33.2
9	29.2	42.6	23.5	52.1	23.7	68.1	26.1	29.7	84.5	30.1	28.8	32.8	30.6
10	17.9	40.2	17.6	83.0	16.3	108.2	16.4	33.1	171.4	15.5	40.0	29.5	59.9
11	7.9	25.8	30.4	32.2	38.2	44.2	38.3	38.1	51.8	48.7	38.8	64.3	63.9
12	125.8	73.2	144.3	128.8	131.3	180.9	138.8	127.4	216.1	143.8	182.6	140.1	165.1
13	13.9	27.3	14.9	58.2	20.5	102.2	23.2	32.4	131.5	32.9	30.5	35.4	33.9
14	45.4	63.3	47.4	107.3	48.0	135.5	47.5	86.6	181.3	45.9	78.6	71.9	72.6
15	60.9	55.5	72.9	88.4	97.0	138.2	96.0	56.9	170.1	115.8	81.3	126.1	95.5
16	29.8	73.7	38.1	96.7	31.9	147.6	23.7	71.7	187.2	50.4	98.8	55.0	54.0
17	3.0	0.7	2.9	13.5	3.3	10.1	3.8	25.1	20.3	5.7	16.3	14.4	12.5
18	4.8	23.6	5.1	52.0	7.2	79.7	7.4	21.6	104.1	11.9	20.2	17.2	23.3
Avg.	26.8	36.6	30.9	63.5	31.8	76.6	33.6	53.1	107.8	40.9	56.4	46.4	52.7
Min.	2.6	0.7	2.9	13.5	2.3	10.1	2.6	21.6	20.3	3.1	16.3	4.7	12.5
Max.	125.8	73.7	144.3	128.8	131.3	180.9	138.8	127.4	216.1	143.8	182.6	140.1	165.1
Coeff. of Var.	113%	59%	110%	46%	106%	63%	102%	52%	52%	90%	69%	79%	67%

TABLE 25. COMPARISON OF GASOLINE TRUCK NO_x EMISSIONS IN GRAMS/MINUTE FROM DIFFERENT DRIVING CYCLES AT THE SAME AVERAGE SPEED (HALF LOAD DATA)

Avg. Speed, kph	8		16		24		32			48		64	
Cycle	SS	Trans	SS	Trans	SS	Trans	SS	Sine	Trans	SS	Sine	SS	Sine
Truck 1	0.28	0.48	0.35	1.04	0.28	1.86	0.86	2.90	2.09	3.01	2.32	6.33	7.39
2	0.19	0.42	0.27	1.84	0.27	2.25	0.85	2.75	3.70	1.56	2.57	4.84	4.79
3	0.68	1.13	1.51	2.46	1.25	3.47	3.30	8.09	5.35	6.14	7.80	9.00	8.55
4	0.40	0.56	0.51	1.18	0.73	1.94	1.00	2.86	2.75	2.05	3.43	5.52	4.88
5	0.57	0.61	0.67	0.87	0.67	1.89	1.41	2.63	2.05	3.68	2.79	8.69	7.01
6	0.82	0.89	1.21	2.01	1.17	2.83	2.58	5.22	4.12	4.24	6.51	7.88	8.71
7	0.56	0.49	0.68	1.51	0.78	2.16	1.54	3.73	3.11	2.76	4.06	5.60	5.92
8	0.24	0.36	0.27	0.84	0.24	2.73	0.88	2.93	3.54	3.22	3.64	10.01	11.08
9	0.42	0.70	0.50	1.44	0.68	2.47	1.70	4.12	3.33	5.31	4.51	10.25	8.71
10	1.12	0.90	2.13	2.04	1.90	3.49	2.93	6.03	4.32	5.80	8.02	17.92	18.78
11	0.48	1.30	0.75	2.48	0.89	4.95	1.07	3.32	5.39	3.09	5.21	7.23	6.10
12	0.43	0.46	0.69	0.86	0.31	1.26	0.52	1.90	1.49	3.36	3.28	8.79	6.50
13	0.81	1.60	1.11	2.96	2.08	4.11	2.83	3.92	5.99	6.48	6.19	16.35	13.95
14	0.67	0.49	0.82	0.82	0.86	1.17	1.15	1.68	1.45	1.61	2.23	4.66	3.44
15	0.37	1.15	0.71	2.02	1.35	3.70	1.01	10.43	3.74	3.14	9.92	4.59	7.90
16	0.93	0.48	1.05	0.68	1.01	1.08	1.53	3.17	1.39	3.41	4.41	8.05	8.11
17	0.64	0.44	0.66	1.11	0.67	1.72	0.84	2.66	2.60	1.40	2.52	3.73	3.59
18	0.74	0.95	0.69	1.54	0.99	2.24	1.32	2.96	3.50	2.68	5.83	7.63	9.40
Avg.	0.57	0.75	0.81	1.54	0.90	2.52	1.52	3.96	3.33	3.50	4.74	8.17	8.05
Min.	0.19	0.36	0.27	0.68	0.24	1.08	0.52	1.68	1.39	1.40	2.23	3.78	3.44
Max.	1.12	1.60	2.13	2.96	2.08	4.95	3.30	10.43	5.99	6.48	9.92	17.92	18.78
Coeff. of Var.	43%	48%	57%	44%	58%	42%	55%	56%	41%	44%	47%	46%	46%

TABLE 26. COMPARISON OF GASOLINE TRUCK FUEL RATE IN GRAMS/MINUTE FROM DIFFERENT DRIVING CYCLES AT THE SAME AVERAGE SPEED (HALF LOAD DATA)

Avg. Speed, kph	8		16		24		32			48		64	
Cycle	SS	Trans	SS	Trans	SS	Trans	SS	Sine	Trans	SS	Sine	SS	Sine
Truck 1	98.9	47.3	103.7	88.6	90.9	98.3	110.8	125.0	153.0	123.7	132.9	184.1	187.9
2	104.8	85.3	118.6	131.0	114.2	130.5	150.1	175.1	177.0	173.1	181.0	248.3	242.5
3	98.5	76.8	130.4	119.3	108.0	140.8	155.8	187.4	185.9	183.4	190.5	228.4	194.1
4	67.1	61.4	85.1	103.7	85.6	116.4	125.3	183.7	168.9	157.2	179.7	220.6	223.7
5	96.6	58.6	94.0	110.6	78.7	112.0	105.6	138.9	180.9	126.2	157.1	201.2	223.8
6	120.3	78.5	135.5	126.1	117.7	140.0	167.6	199.8	187.1	201.2	217.4	240.9	252.0
7	151.0	99.2	158.7	152.4	158.4	168.9	222.6	244.8	225.9	234.5	251.7	271.5	274.5
8	106.5	81.3	107.3	127.7	92.9	143.4	129.3	179.6	198.3	154.8	164.9	226.4	232.3
9	87.9	76.1	89.1	107.9	89.9	149.0	127.1	140.8	182.3	155.9	148.1	225.3	209.0
10	161.6	96.8	195.3	159.3	167.6	207.1	181.1	183.7	286.3	203.4	219.2	339.7	347.9
11	115.0	93.6	141.8	126.5	156.0	183.7	152.0	176.3	202.3	219.1	210.1	264.3	254.7
12	166.7	101.0	203.4	167.9	168.8	229.6	182.3	208.0	272.0	278.0	301.3	353.0	370.8
13	146.0	91.4	163.6	147.6	196.7	208.9	201.3	192.2	265.7	271.7	222.4	326.6	308.4
14	185.4	114.7	206.3	187.0	187.0	226.5	198.7	237.4	283.3	257.2	245.4	385.6	372.7
15	148.8	115.4	190.2	176.3	250.8	249.7	218.5	251.5	274.4	298.7	305.1	300.9	301.6
16	158.3	106.3	167.2	149.1	149.1	206.1	158.6	204.1	249.1	223.7	250.4	270.5	270.0
17	119.5	62.8	125.0	102.6	100.3	123.5	146.1	172.8	172.6	174.1	171.8	220.8	212.6
18	146.1	104.8	174.0	161.5	211.1	216.9	227.5	178.6	270.3	261.3	262.1	3[illegible]0.3	345.6
Avg.	126.6	86.2	143.8	135.8	140.2	169.5	164.5	187.8	218.6	204.8	211.7	269.4	268.0
Min.	67.1	47.3	85.1	88.6	78.7	98.3	105.6	125.0	153.0	123.7	132.9	184.1	187.9
Max.	185.4	115.4	206.3	187.0	250.8	249.7	227.5	251.5	286.3	298.7	305.1	385.6	372.7
Coeff. of Var.	26%	23%	28%	21%	36%	28%	23%	18%	21%	26%	24%	22%	22%

three 32 kph driving cycles used in Contract 68-03-2147 and the percent time in various vehicle speeds for the SARR were compared. This comparison is shown in Table 27. The comparison is shown in miles/hour, since the SARR data was obtained and analyzed in those units. As an aid to visualizing the differences between the SARR and the dynamometer driving cycles, the cumulative percent time for each of the cycles is shown in Figure 12. As can be seen from the table and the figure, the dynamometer driving cycles are all fairly similar to each other. The SARR, however, differs from the dynamometer cycles in that it has less time at idle, more time between idle and 32 kph, and less time between 50 and 80 kph.

The comparison of the average engine rpm distribution for all gasoline trucks driven on the three dynamometer cycles and the average SARR engine rpm distribution is shown in Table 28, together with the rpm distributions from CAPE-21 and the Ethyl Truck and Bus Study (ETABS). The cumulative percent time is shown in Figure 13 for the SARR, the 18 truck dynamometer study, and the New York CAPE-21 data.

From the table and figure, it is evident that the three cycles do not show good agreement. The New York CAPE-21 data has over 20 percent of the time at idle and another 20 percent under 1000 rpm. The 18 truck dynamometer study has the same percent time at idle as the New York CAPE-21 but much less time at speeds under 2000 rpm and more time than the New York CAPE-21 at speeds above 2000 rpm. While the SARR has less time at idle, it has more time in the 1000 to 2000 rpm range than either of the other two cycles. The difference between the dynamometer cycle data and the CAPE-21 data is of interest, since it is understood that the dynamometer cycles were developed from the New York CAPE-21 data. However, the analysis of Item 5 showed that the rpm profile varied from truck-to-truck. Therefore, the differences between the dynamometer cycles and the CAPE-21 data could be caused by a different fleet composition. Also, the composite average speed of the New York CAPE-21 trucks is not known by SwRI.

Item 9 - Can fuel rate and emissions be highly correlated with percent time at idle?

For this item, the data from the nine single axle trucks was used. The relationship of fuel flow and emissions to percent time at idle for the various driving cycles was to be investigated by normalizing the variables. The technique proposed to normalize the fuel flow and emissions was to ratio the fuel and emission values for the various percent times at idle to the value at 100 percent idle. This was done and linear regression performed on the normalized variables. Table 29 shows the percent time at idle for the various driving cycles used. The correlation coefficients between normalized HC, CO, NO_x and fuel flow and percent time at idle are -0.33, -0.39, -0.60, and -0.81, respectively. The scatter plots for HC, CO, NO_x, and fuel flow are shown in Figures 14 through 17, respectively. The scatter plot of the normalized data is also shown on same figure. From this analysis, it appears that the emissions do not correlate with driving cycle time at idle sufficiently to be able to predict emissions for driving cycles from idle emissions. Depending on the accuracy needed, the fuel flow relationship may be adequate.

Examining the scatter plots for CO, NO_x, and fuel, it becomes evident

TABLE 27. PERCENT TIME AND CUMULATIVE PERCENT TIME SPENT IN VEHICLE SPEED INTERVALS FROM THE 32 kph TRANSIENT DRIVING CYCLES OF CONTRACT 68-03-2147 AND FROM SAN ANTONIO ROAD ROUTE STUDIES

	Single Unit 2 Axle (2D)		Single Unit 3 Axle (3D)		Tractor Trailer (TT)		SARR	
Speed Interval kph	% Time	Cum. % Time	% Time	Cum. % Time	% Time	Cum. % Time	% Time	Cum. % Time
0-3.2	28.95	28.95	37.62	37.62	37.50	37.50	14.54	14.54
3.2-6.4	1.50	30.45	0.81	38.43	0.80	38.30	2.51	17.05
6.4-9.7	1.83	32.28	4.06	42.49	3.99	42.29	2.29	19.34
9.7-12.9	1.50	33.78	0.95	43.44	0.40	42.69	2.60	21.94
12.9-16.1	4.49	38.27	5.55	48.99	5.45	48.14	3.25	25.19
16.1-19.3	1.50	39.77	1.76	50.75	0.78	48.92	3.98	29.17
19.3-22.5	1.83	41.60	0.95	51.70	0.66	49.58	4.64	33.81
22.5-25.7	4.83	46.43	5.55	57.25	3.72	53.30	4.89	38.70
25.7-29.0	1.66	48.09	0.68	57.93	0.66	53.96	5.26	43.96
29.0-32.2	5.16	53.25	5.55	63.48	4.79	58.75	5.65	49.61
32.2-35.4	1.33	54.58	0.95	64.43	0.93	59.68	6.15	55.76
35.4-38.6	1.50	56.08	0.81	65.24	1.06	60.74	6.03	61.79
38.6-41.8	6.16	62.24	3.79	69.03	4.79	65.53	6.15	67.94
41.8-45.1	1.66	63.90	0.14	69.17	0.93	66.46	5.84	73.78
45.1-48.3	6.82	70.72	1.62	70.79	5.59	72.05	5.04	78.82
48.3-51.1	0.83	71.55	0.28	71.07	0.40	72.45	4.08	82.90
51.5-54.7	0.67	72.22	0.14	71.21	0.40	72.85	2.75	85.65
54.7-57.9	3.00	75.22	1.89	73.10	1.20	74.05	1.88	87.53
57.9-61.1	0.83	76.05	0.28	73.38	0.53	74.58	1.45	88.98
61.1-64.4	7.15	83.20	3.25	76.63	1.86	76.44	1.29	90.27
64.4-67.6	1.00	84.20	0.81	77.44	0.53	76.97	1.67	91.94
67.6-70.8	0.83	85.03	0.68	78.12	0.40	77.37	1.57	93.51
70.8-74.0	4.66	89.69	4.47	82.59	5.75	83.09	1.57	95.08
74.0-77.2	0.83	90.52	0.27	82.86	0.53	83.62	1.70	96.78
77.2-80.4	2.83	93.35	2.44	85.30	4.52	88.14	1.48	98.26
80.4-83.7	0.33	93.68	0.28	85.58	0.27	88.41	0.81	99.07
83.7-86.9	0.66	94.00	0.28	85.86	0.27	88.68	0.50	99.57
86.9-90.1	5.66	99.66	3.11	88.97	0.27	88.95	0.19	99.76
90.1-93.3			0.28	89.25	0.27	89.22	0.12	99.88
93.3-96.5			10.83	100.08	10.78	100.00	0.12	100.00
Avg. Spd. kph	33.31		31.78		32.78		32.18	

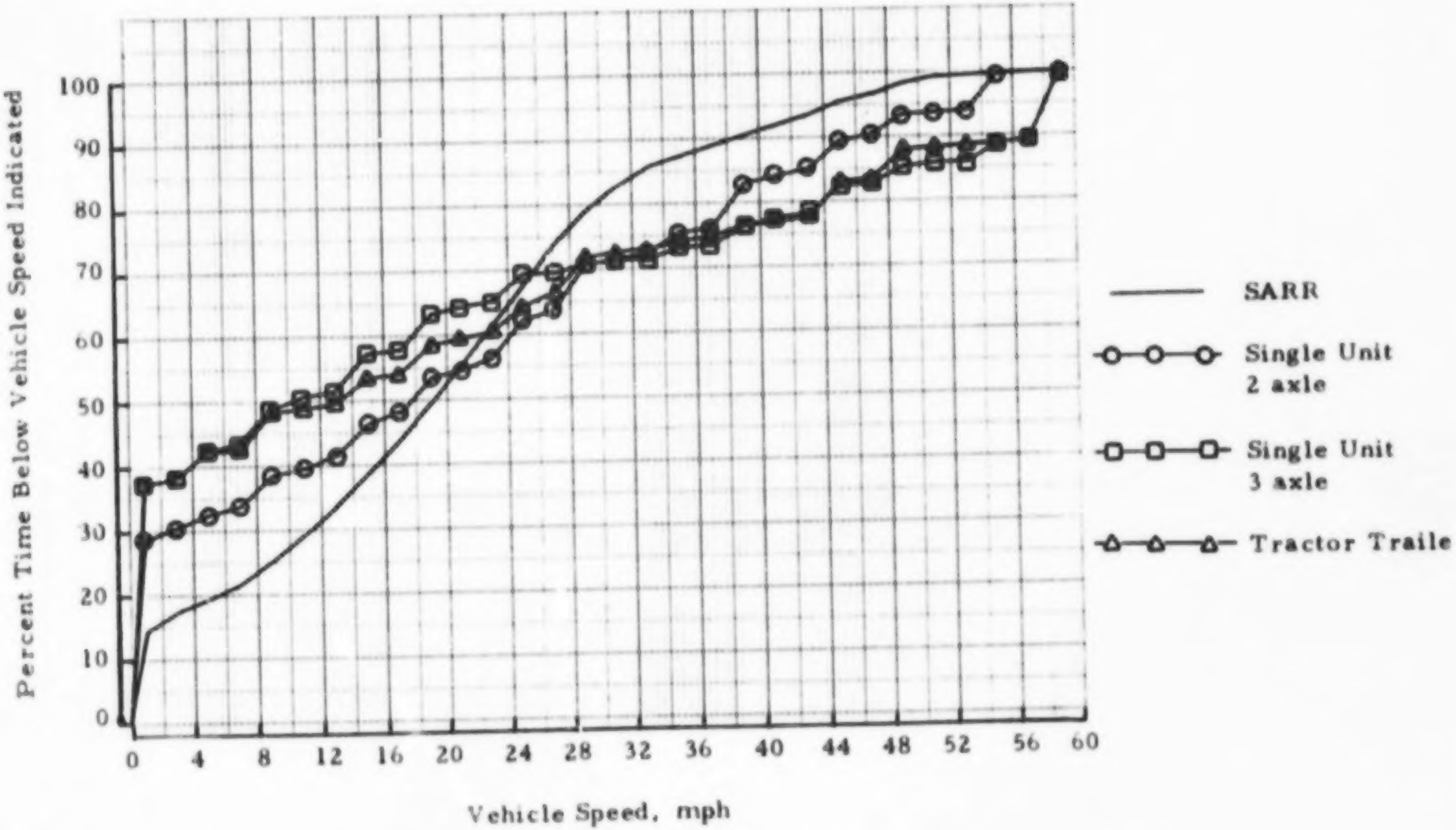


FIGURE 12. CUMULATIVE PERCENT TIME VERSUS VEHICLE SPEED FOR THE SAN ANTONIO ROAD ROUTE AND THREE 20 mph DRIVING CYCLES FROM CONTRACT 68-03-2147

TABLE 28. COMPARISON OF TIME SPENT IN VARIOUS RPM INTERVALS FOR SEVERAL GASOLINE-POWERED TRUCK STUDIES

rpm(a)	CAPE-21 L. A.	CAPE-21 N. Y.	ETABS* (All cities)	SARR**	18 Truck Dyno Study***
200	0.00	0.17	0.02	0.00	0.13
400	0.53	6.66	6.59	0.15	0.03
600	9.33	21.40	20.81	5.20	9.11
800	6.74	13.04	12.32	10.40	21.53
1000	6.69	10.72	8.53	5.36	3.26
1200	4.18	8.64	8.28	6.20	3.14
1400	4.28	7.13	8.01	8.94	3.13
1600	5.01	6.70	7.55	11.65	3.34
1800	5.82	5.68	8.13	12.94	4.25
2000	7.21	4.50	5.23	11.00	4.91
2200	6.31	4.08	3.92	7.74	6.59
2400	7.79	2.94	2.97	4.46	8.71
2600	10.74	2.31	2.54	3.76	7.53
2800	11.80	1.72	2.00	3.00	7.72
3000	6.68	1.21	1.38	2.40	6.54
3200	2.57	0.79	0.96	2.00	4.88
3400	1.18	0.44	0.61	0.90	2.90
3600	0.56	0.21	0.34	0.50	1.36
3800	0.41	0.06	0.14	0.20	0.28
4000	0.26	0.02		0.08	0.03
4200	0.23	0.01			
4400	0.03	0.00			

---

* ETABS - Ethyl Truck and Bus Study

** SARR - San Antonio Road Route Studies

***18 Truck Dyno Study - 32 kph driving cycles from Contract 68-03-2147

(a)rpm is mid-point of interval for all but SARR data. For SARR data rpm is end of interval.

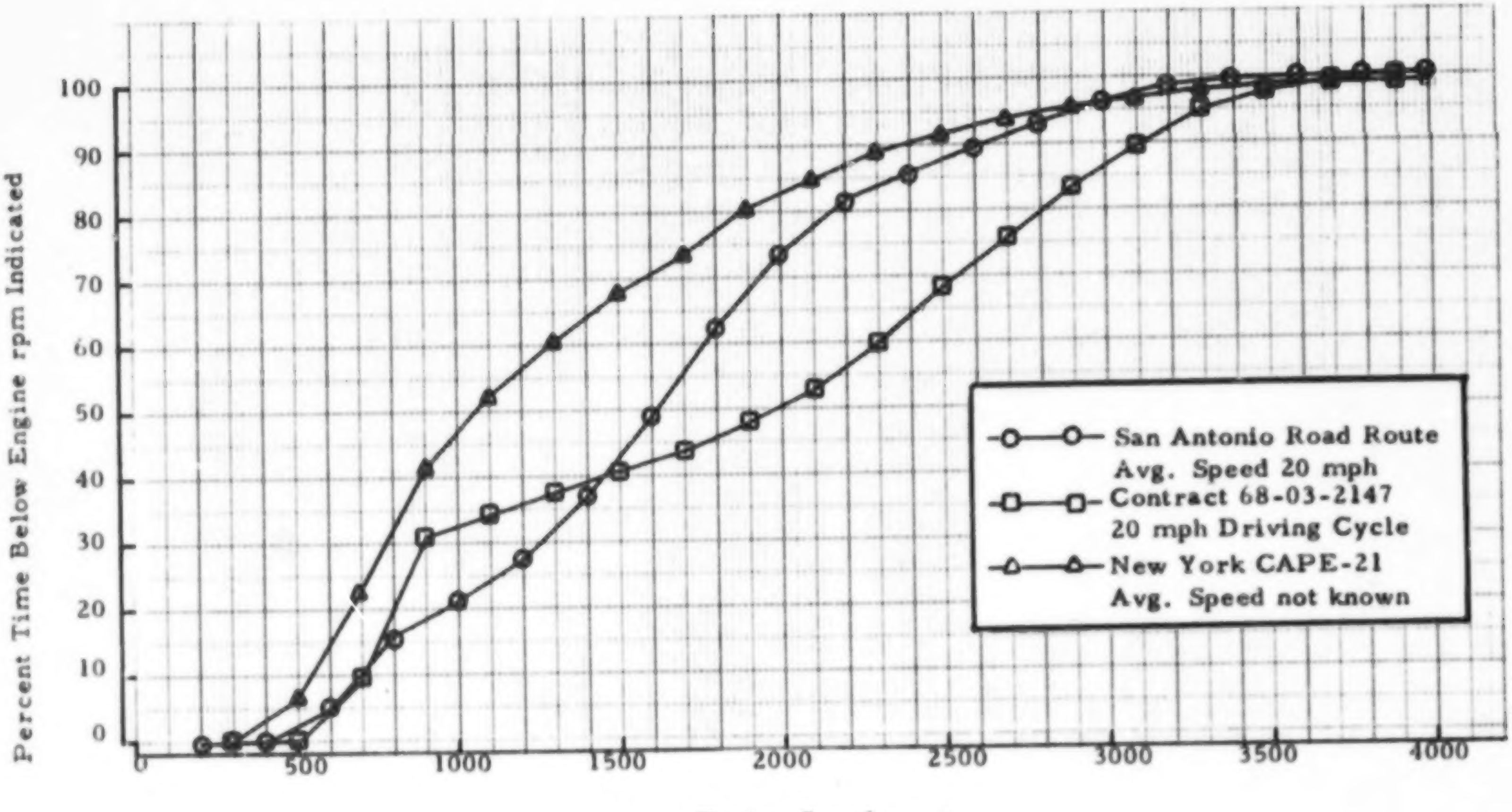


FIGURE 13. CUMULATIVE PERCENT TIME VERSUS ENGINE SPEED FOR GASOLINE-POWERED TRUCKS TESTED ON CAPE-21, SAN ANTONIO ROAD ROUTE, AND 20 mph DRIVING CYCLES FROM CONTRACT 68-03-2147

TABLE 29. PERCENT TIME IN IDLE MODE FOR VARIOUS DRIVING CYCLES

Test Description	Cycle Description*	Average Speed, kph	Percent Time at Idle
Idle SS		0	100
5 Average	D2GAS	8	56.7
10 Average	D2GAS	16	42.4
15 Average	D2GAS	24	37.9
20 Average	D2GAS	32	21.2

*See Reference 13 for complete description of cycles.

TABLE 30. EXPONENTIAL CURVE FIT RESULTS FOR CO AND NO_x EMISSIONS AND FUEL CONSUMPTION AS A FUNCTION OF DRIVING CYCLE PERCENT TIME AT IDLE

form of equation: $y = ae^{bx}$

	a	b	Correlation Coefficient
Normalized CO, g/min	60.54	-0.012	-0.73
NO_x, g/min	18.31	-0.071	-0.85
Normalized Fuel Consumption, g/min	249.66	-0.020	-0.94

Y = CO or NO_x emission
X = percent time at idle
Sample size: 9 gasoline powered trucks

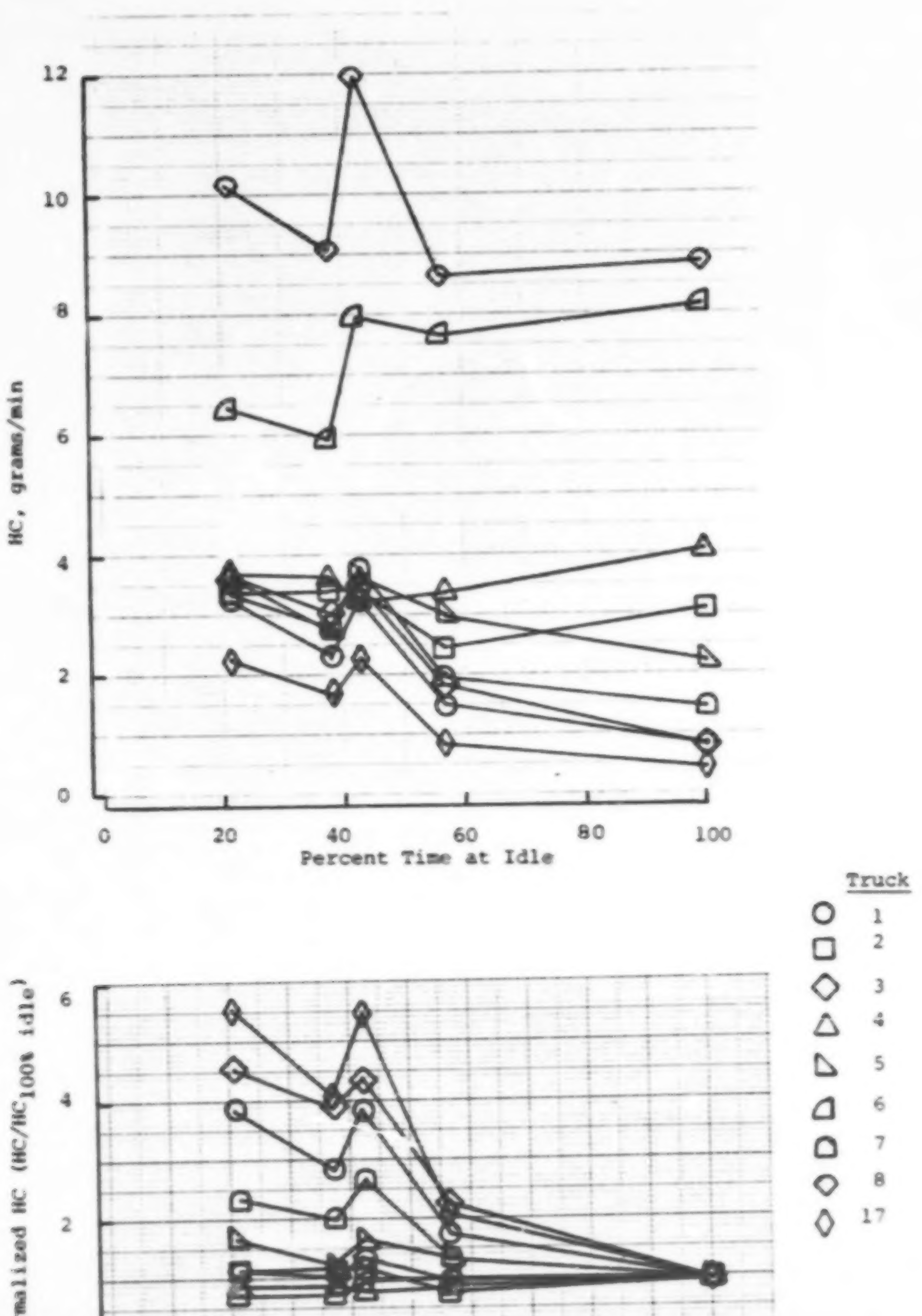


FIGURE 14. HC EMISSIONS AS A FUNCTION OF PERCENT TIME AT IDLE FOR NINE GASOLINE POWERED TRUCKS

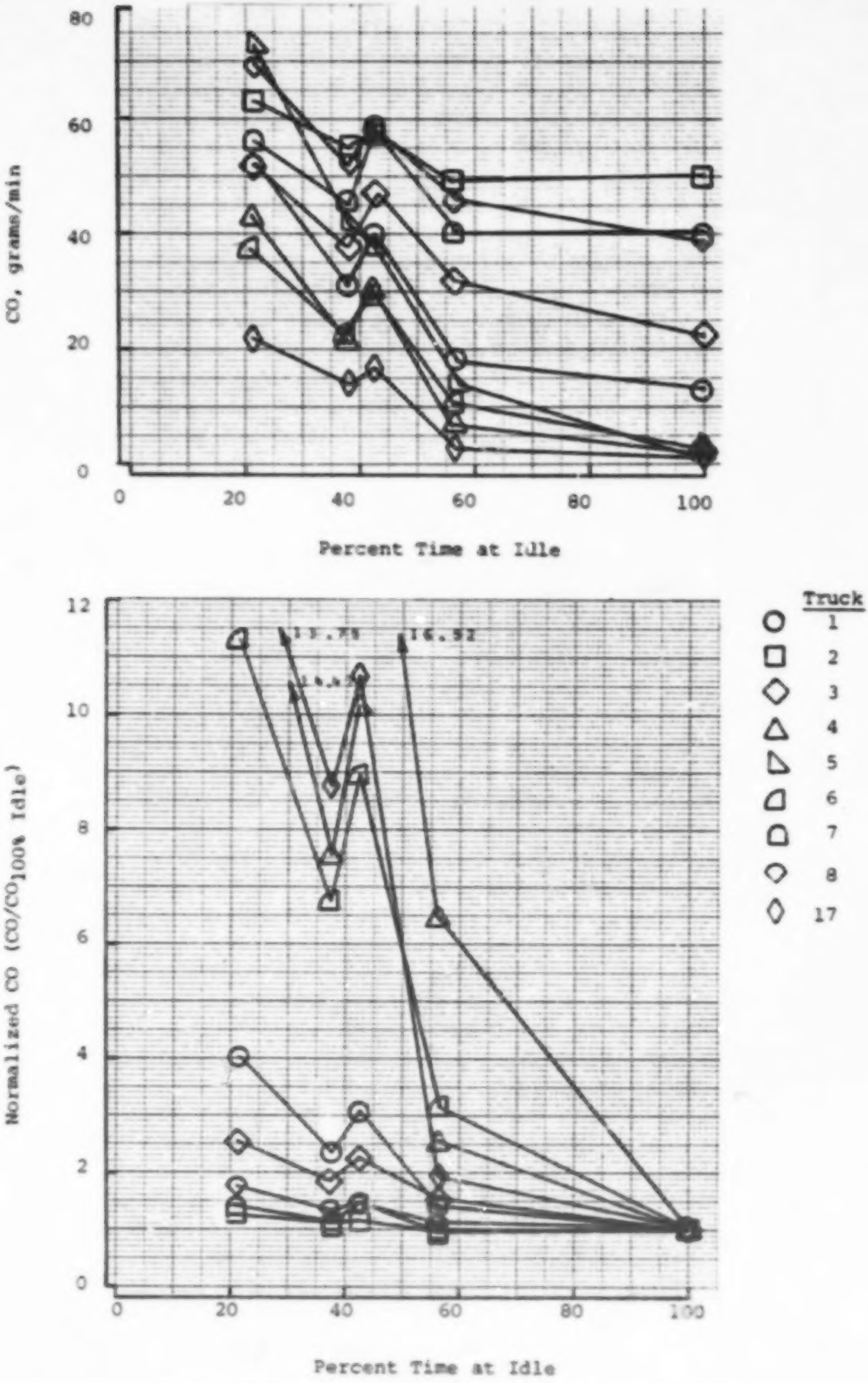


FIGURE 15. CO EMISSIONS AS A FUNCTION OF PERCENT TIME AT IDLE FOR NINE GASOLINE POWERED TRUCKS

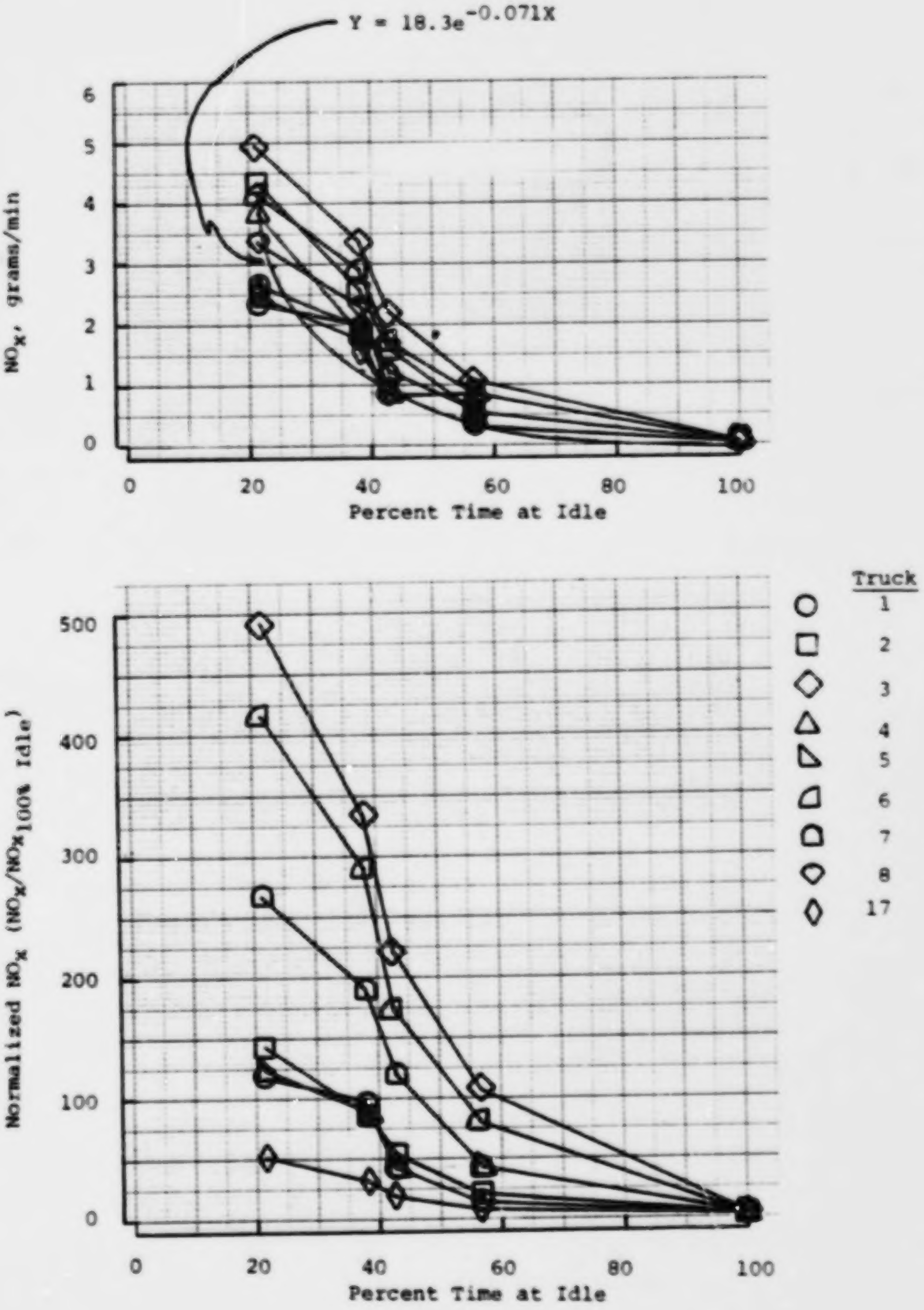


FIGURE 16. NO_x EMISSIONS AS A FUNCTION OF PERCENT TIME AT IDLE FOR NINE GASOLINE POWERED TRUCKS

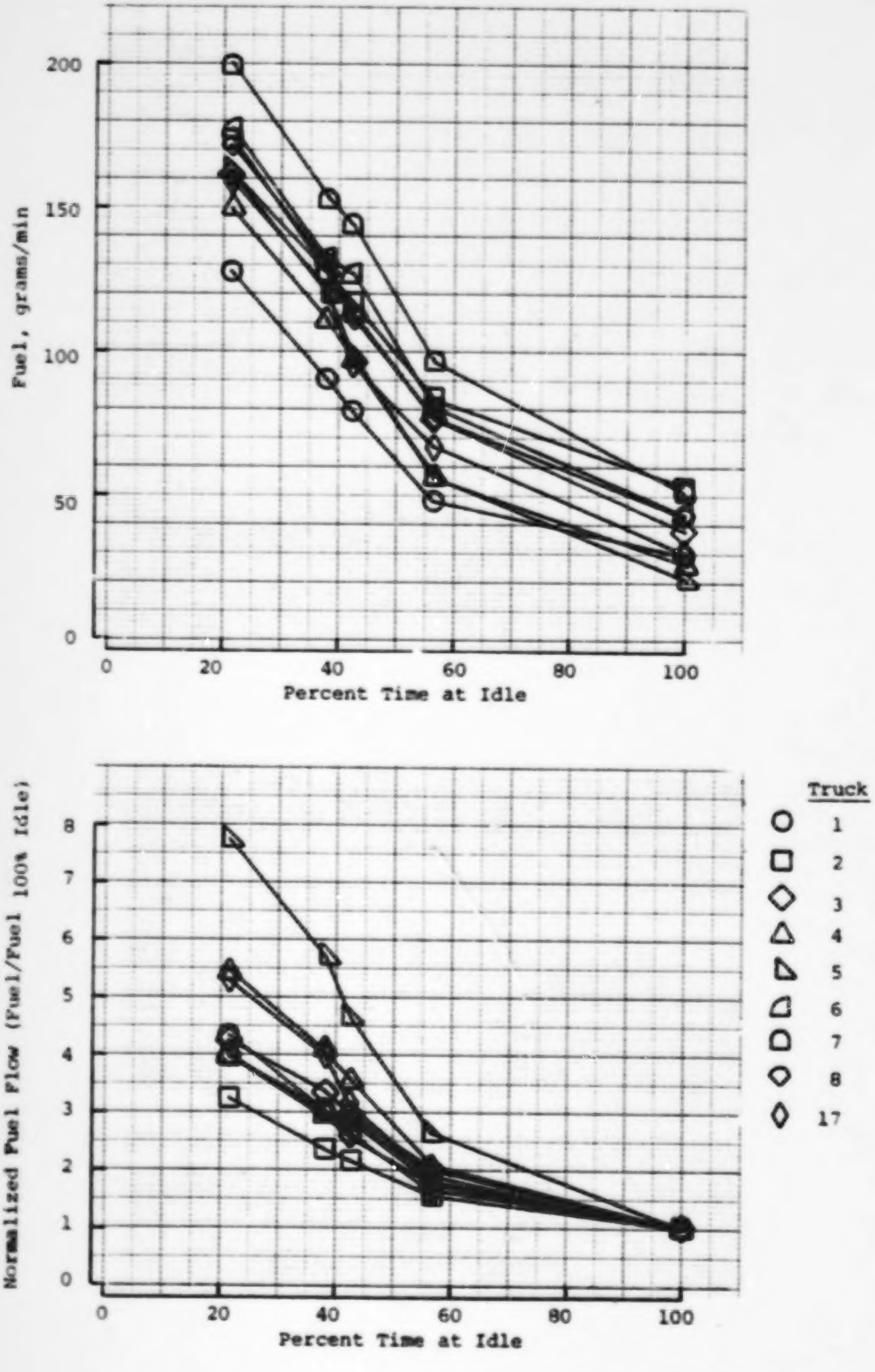


FIGURE 17. FUEL CONSUMPTION AS A FUNCTION OF PERCENT TIME AT IDLE FOR NINE GASOLINE POWERED TRUCKS

that the method used to normalize the data may not be the most appropriate. Another method would be to use the average emission or fuel level at the 21.2 percent idle condition and adjust the values of the emissions and fuel for each truck at all idle levels by subtracting the amount that each truck varies from the average at the 21.2 percent idle point. Thus, each truck's curve retains the same shape as the unnormalized curve and is simple moved up or down the y axis. In examining the plots of the emissions and fuel consumption, it was felt that HC would not benefit substantially from this alternate analysis and that NO_x need not be normalized at all. However, the CO and fuel consumption relationships might be improved using this method.

Figure 18 shows the CO emissions normalized as explained in the preceeding paragraph. This method results in a better linear fit. The correlation coefficient is -0.66. From the appearance of the scatter plot, a nonlinear curve would probably fit the data better. However, the apparent discontinuity between 37.9 percent idle and 42.4 percent idle that can be seen for all trucks on the CO emissions raises the question of whether the CO emissions are really a function of the percent time at idle or if it is just a fortuitous relationship for these particular cycles.

It appears that a better fuel flow relationship could also be obtained by this normalization technique. The scatter plot of fuel consumption normalized by this technique as a function of percent time at idle is shown in Figure 19. It is evident that this relationship would fit a nonlinear curve better than a straight line, so the straight line regression was not performed.

Thus, it appeared that the correlation to percent time at idle for CO and NO_x emissions and fuel consumption could be improved by using something other than a straight line. An exponential curve fit of the form $y = ae^{bx}$ was tried on the normalized CO, normalized fuel consumption, and NO_x. A good fit was obtained for fuel consumption as can be seen in Figure 19. It is likely that some other curvilinear function would provide a better fit for NO_x. The coefficients of the exponential curve fit are shown in Table 30.

Item 10 - Heavy Duty Emissions Factor Analysis

Four items of analysis were required to assess the effects of speed, load, and power/load ratio on heavy-duty vehicles. The analyses need to be performed using several available heavy-duty data bases. The data bases to be considered are (1) 25 gasoline trucks tested over SARR, (2) 10 precontrolled gas trucks tested over the SARR, and (3) 18 gas trucks tested over a transient 20 mph driving cycle. For this item, the data and results are presented in mixed metric-English units as requested, since the results will be used in mixed metric form in another EPA publication.

> Item 10-1 - For each of the three data bases, a regression should be performed for emissions as the dependent variable, weight/power ratio as the independent variable. The weight is the vehicle test weight and the power is CID for gasoline trucks. The regression should be linear, unless

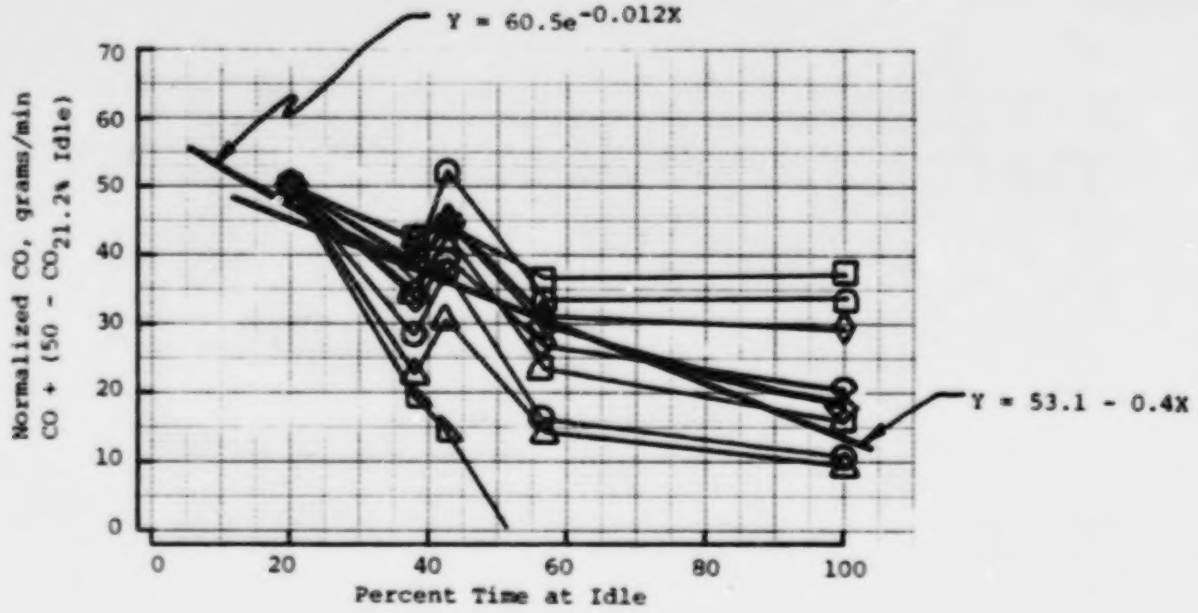


FIGURE 18. NORMALIZED CO AS A FUNCTION OF PERCENT TIME AT IDLE

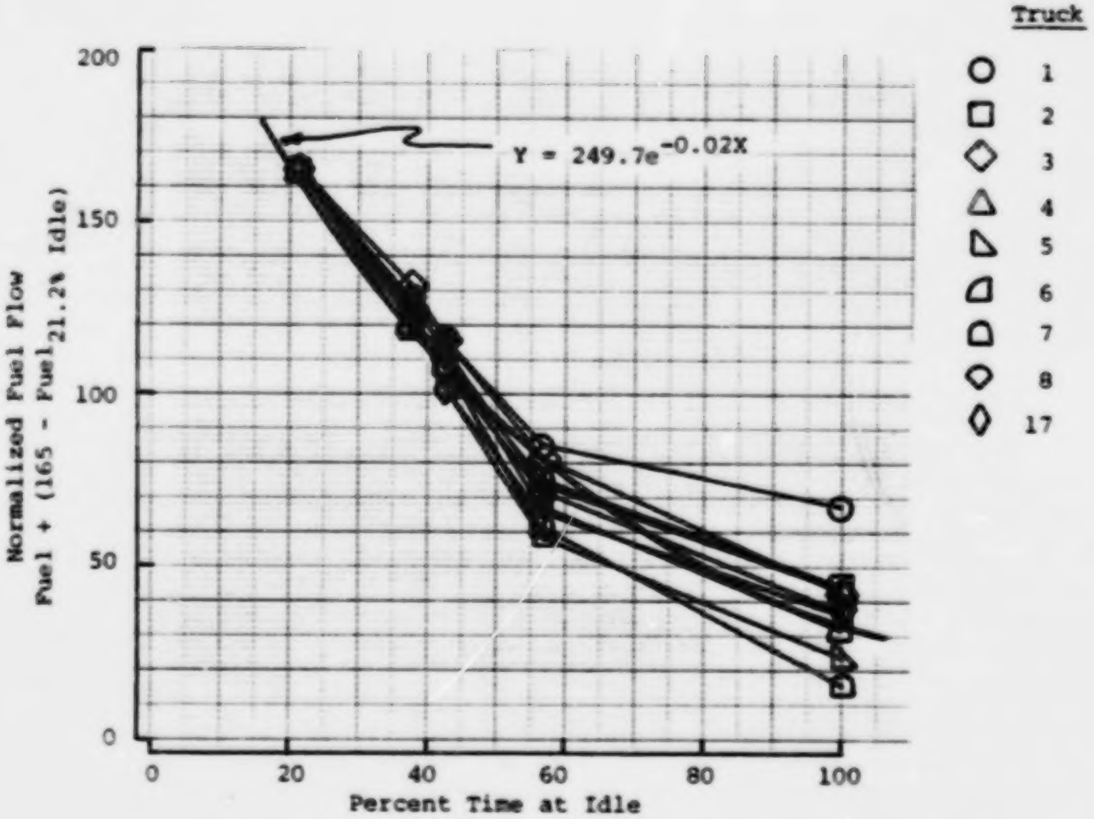


FIGURE 19. NORMALIZED FUEL CONSUMPTION AS A FUNCTION OF PERCENT TIME AT IDLE

> a plot of the data indicate a better functional form. Within each data base, separate regressions should be performed for each of the following model year groupings: pre-1970 gas, 1970-1973 gas, 1974-1975 gas, and the 1975 California gas.
>
> All emission data should be expressed in grams/mile. For data bases 1 and 2, the SARR emission data should be used (HC, CO, NO_x, and FC). For data base 3, the 20 mph emission data should be used (HC, CO, NO_x, and FC). If multiple tests were performed on the same truck at different loads, these data points should be included and assumed independent. The average weight/power ratio should be computed for each of the data base/model year groups.

Table 31 contains the average weight/CID ratio for each of the truck groupings. Also available in the table are average test weight, average CID, and average mileage of each group.

Linear regression analyses were performed for each truck group with emissions or fuel consumption as the dependent variable and weight/CID ratio as the independent variable. The regression equations for each emission and fuel consumption of each truck group are contained in Table 32.

Examining the results of the regression analyses shown in Table 32, it appears that weight/CID has a significant effect on emissions and fuel consumption for about one half of the truck groups. Since displacement is, in general proportional to some design point power, the weight/CID ratio could be thought of as a weight/rated power ratio. The slopes of the equations HC, CO and fuel are all positive, indicating that for a given size engine, as vehicle weight increases, fuel consumption and HC and CO emissions also increase. This result is expected for fuel consumption. Since it takes more work to move a larger vehicle, the same size engine would naturally require more fuel. The physical reasons behind the increase in HC and CO emissions with increased weight/CID are not as apparent. For CO, one possible explanation is that the "power valve" is open more at higher weight/CID ratios causing an increase in CO.

The regression equations, in general, had small coefficients of determination (r^2), even on truck groups where the emissions and weight/CID relationship was indicated to be significant. In an effort to improve the coefficients of determination, an exponential curve fit was also performed since examination of the plots indicated that an exponential equation might better fit some of the data. While this regression analysis did improve some of the coefficients of determination slightly, it also decreased others. Overall, it was felt that there was little to be gained by using an exponential fit.

The small values of r^2 and large standard error values indicate a considerable amount of data scatter. This should not be too surprising, since it has been shown in past studies(19) that engine model (i.e., manufacturer, size, ancilary equipment and model year) was the most

TABLE 31. AVERAGES OF SOME IMPORTANT VARIABLES FROM SEVERAL HEAVY-DUTY GASOLINE TRUCK STUDIES

Group*	Average Wt., lbs	Average Wt./CID	Average Mileage	Average CID	No. of Trucks
1. SARR Pre-1970 Gas	16,512	49.72	58,845	344.4	10
2. SARR 1970-1973 Gas	16,341	45.92	23,881	353.2	25
3. 1974-1975 Gas	21.772	54.10	11,112	399.	24
4. Pre-1970 Gas	21,892	61.46	68,413	352.5	12
5. 1970-1973 Gas	20,933	55.27	53,853	313.85	12

* Data Source:
Group 1 - EPA Contract 68-03-0441
Group 2 - EPA Contract EHS 70-113
Group 3 to 5 - EPA Contract 68-03-2147

TABLE 32. RESULTS OF REGRESSION ANALYSIS OF EMISSIONS AND FUEL CONSUMPTION AS A FUNCTION OF WEIGHT/CID FOR VARIOUS GASOLINE TRUCK GROUPS

Group	Constant	Wt/CID ± Std.Dev.	r^2	Std. Err.	No. of Trucks
		HC Emissions			
1. SARR Pre-1970 Gas	15.513	0.408 ± 0.840	0.029	31.96	10
2. SARR 1970-1973 Gas	-15.818	0.716 ± 0.184	0.397***	7.242	25
3. 1974-1975 Gas	10.572	0.152 ± 0.063	0.212*	6.717	24
4. Pre-1970 Gas	20.683	0.105 ± 0.131	0.061	10.956	12
5. 1970-1973 Gas	0.437	0.364 ± 0.085	0.647**	7.549	12
6. 1975 California Gas	6.366	0.067 ± 0.036	0.464	2.542	6
		CO Emissions			
1. SARR Pre-1970 Gas	222.769	0.321 ± 1.078	0.011	41.039	10
2. SARR 1970-1973 Gas	12.506	4.095 ± 2.984	0.076	120.379	25
3. 1974-1975 Gas	40.448	4.799 ± 1.191	0.425***	127.668	24
4. Pre-1970 Gas	123.319	4.800 ± 1.019	0.690***	85.419	12
5. 1970-1973 Gas	207.919	1.917 ± 2.094	0.077	185.979	12
6. 1975 California Gas	-0.357	3.479 ± 0.999	0.752*	70.802	6
		NO_x Emissions			
1. SARR Pre-1970 Gas	0.728	0.125 ± 0.065	0.319	2.459	10
2. SARR 1970-1973 Gas	8.788	0.037 ± 0.098	0.006	3.971	25
3. 1974-1975 Gas	11.161	0.016 ± 0.027	0.016	2.899	24
4. Pre-1970 Gas	10.113	-0.063 ± 0.026	0.362*	2.202	12
5. 1970-1973 Gas	10.109	-0.017 ± 0.047	0.014	4.158	12
6. 1975 California Gas	6.482	0.043 ± 0.013	0.749*	0.893	6
		Fuel Consumption			
1. SARR Pre-1970 Gas	0.071	0.002 ± 0.001	0.714**	0.020	10
2. SARR 1970-1973 Gas	0.066	0.003 ± 0.001	0.336	0.030	25
3. 1974-1975 Gas	0.159	0.002 ± 0.000	0.425***	0.040	24
4. Pre-1970 Gas	0.156	0.001 ± 0.000	0.544**	0.035	12
5. 1970-1973 Gas	0.165	0.001 ± 0.001	0.166	0.051	12
6. 1975 California Gas	0.150	0.001 ± 0.000	0.776*	0.028	6

Notes:
1. Weight = truck wt/1000 = lb/1000
2. CID = cubic inch displacement for both gasoline and diesel
3. Fuel is in gallons/mile
4. Significance: * = 0.05
   ** = 0.01
   *** = 0.001
5. Group 1 - EPA Contract 68-03-0441
   Group 2 - EPA Contract EHS 70-113
   Group 3 - EPA Contract 68-03-2147
   to 6

significant variable in explaining differences in emission levels from a large group of trucks. Thus, the data used in this analysis is in reality what statisticians term "nested" data; that is, within the data, there are individual slopes. Unfortunately, in this study, there are insufficient data to identify each of the groups.

One other caution should be mentioned before ending the discussion on this item. The data points used for each truck group are, in general, few in number. Also, the weight/CID range covered by the SARR trucks is small. To aid in comparison of the data base average emissions, average emissions for each data base are given in Table 33.

> Item 10-2 - For each of the model year groups within data base 3, plots should be made for emissions versus average speed. The speed cycles to be considered are 5, 10, 15, and 20 mph transient cycles; 30 and 40 mph sinusoidal cycles; and 55 mph steady-state cycle. The half load data points should suggest an appropriate regression form (log (emissions) provided the best fit for light-duty with a linear and quadratic term for speed). Speed should be expressed in mph and emissions in grams/mile, and fuel consumption in gallons/mile.
>
> These regression equations will be normalized to either the average speed of the SARR or the average speed of the CAPE-21 data. The normalization will be performed by EPA.
>
> All trucks of a given model year group will be combined for the regressions unless examination of individual truck plots indicates that a better approach would be to regress each truck separately and average those results.

As mentioned in the discussion of Item 10-1, engine model has been shown to be a significant variable in studies of truck emissions. The trucks within data base 3, the 18 gasoline-powered trucks tested at the seven different average speed conditions, provide an excellent example of "nested" data.

In order to obtain the best possible prediction model for changes in emissions with speed, a technique involving using indicator (or dummy) variables to change the intercept and, if necessary, slope with individual truck was employed[18]. The data were first fit to this equation.

$$\text{emissions} = b_0 + b_1 \text{ (speed)} + b_2 x_2 + b_3 x_3 + b_4 x_4 + \ldots$$

where $x_i = \begin{cases} 0 \text{ if } i^{th} \text{ truck not used} \\ 1 \text{ if } i^{th} \text{ truck used.} \end{cases}$

In other words, the data is represented by i straight lines, each with a different intercept, but common slope. Next, the data was processed to determine if it could be represented better by straight lines

TABLE 33. AVERAGE EMISSIONS AND FUEL CONSUMPTION FOR SEVERAL HEAVY-DUTY TRUCK GROUPS

Group*	Emissions, grams/mile			Fuel	No. of
	HC	CO	NO_x	gal/mi	Trucks
1. SARR Pre-1970 Gas	35.38	238.0	6.81	0.19	10
2. SARR 1970-1973 Gas	17.08	201.0	10.48	0.18	25
3. 1974-1975 Gas**	18.81	300.08	12.04	0.24	24
4. Pre-1970 Gas	27.13	418.35	6.27	0.24	12
5. 1970-1973 Gas	20.53	313.85	9.14	0.21	12
6. 1975 California Gas	10.12	195.10	8.93	0.23	6

---

* Data Source: Group 1 - EPA Contract 68-03-0441
Group 2 - EPA Contract EHS 70-113
Group 3 to 6 - EPA Contract 68-03-2147

** For Groups 3 to 6, emissions are averages of all trucks in the group at empty, half, and full weight for the 20 mph transient driving cycle.

with different intercepts and different slopes. The equation used was:

$$\text{emissions} = b_0 + b_1\ (\text{speed}) + b_2\ x_2 + b_3\ x_3 + b_4\ x\ b_4\ \ldots + b_{n+1}\ x_{12} + b_{n+2}\ x_{13} + b_{n+3}\ x_{14}\ \cdots$$

where

$$x_i = \begin{cases} 0 \text{ if } i^{th} \text{ truck not used} \\ 1 \text{ if } i^{th} \text{ truck used} \end{cases}$$

$$x_{ii} = \begin{cases} 0 \text{ if } i^{th} \text{ truck not used} \\ x_i * (\text{speed}) \text{ if } i^{th} \text{ truck used.} \end{cases}$$

The hypothesis that the individual slope coefficients do not improve the fit was tested by the F ratio of the residual mean square due to adding extra slope variables to the common slope equation, divided by the residual mean square of the individual slope equation.(18) If the F ratio was not significant at the 0.05 percent significance level, the common slope equation was deemed adequate.

The regression coefficients for this study are given in Tables 34 through 37. Where a common slope could be used, the individual slopes are not given. The plots of the equations are not included in this report but were previously mailed to EPA, ECTD, Ann Arbor, Michigan. It was suggested by EPA that perhaps a logarithmic equation might fit the data since this equation form provided the best fit for light-duty emissions as a function of speed. Therefore, the procedure detailed above was repeated twice. The first equation used was:

$$\ln\ (\text{emissions}) = b_0 + b_1\ (\text{speed}).$$

The second repetition used the equation:

$$\ln\ (\text{emissions}) = b_0 + b_1\ (\text{speed}) + b_2\ (\text{speed}^2).$$

In general, these equation forms gave slightly better coefficients of determination. For CO and NO_x, there was considerable improvement in the coefficients of determination. More importantly, these equation forms permitted the use of a common speed coefficient for each truck group for a given emission. Since the equation forms with the speed squared term gave the best coefficients of determination, it is felt that this equation form should be used to describe the effect of speed on emissions for HC, CO, and NO_x. The equation coefficients for each of the emissions by truck group are given in Tables 38 through 41 .

To aid in normalizing this data base to some given speed, the average emissions for the 20 mph transient driving cycle are given in Table 42 for each truck group. While only the half load data was used in the above analysis, the average emissions at empty and full load are shown for comparison.

> Item 10-3 - For the 1974-1975 gas trucks in data base 3, a regression should be performed with emissions (20 mph cycle) as the dependent variable and mileage as the independent variable.

TABLE 34. RESULTS OF REGRESSION ANALYSIS FOR HC EMISSIONS AS A FUNCTION OF VEHICLE SPEED FOR VARIOUS ENGINE GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Speed Coefficient	r^2	Std. Error	n
Pre-1970 Gas	5	43.454	-1.204±0.177	0.715***	15.415	28
	8	70.198				
	14	62.877				
	16	58.880				
1970-73 Gas	1	27.646	-0.652±0.103	0.728***	8.937	28
	3	28.917				
	9	38.760				
	12	46.602				
1974-75 Gas	2	21.103	-0.355±0.182	0.797***	7.946	56
	4	27,418	-0.522			
	6	51.865	-1.086			
	7	23.131	-0.361			
	10	48.507	-0.919			
	11	26.460	-0.479			
	13	33.755	-0.625			
	15	53.249	-1.073			
1975 Cal. Gas	17	11.615	-0.224±0.087	0.838***	3.778	14
	18	25.171	-0.516			

Note: 1. Equation form: $Y = b_0 + b_1$ (speed)
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 35. RESULTS OF REGRESSION ANALYSIS FOR CO EMISSIONS AS A FUNCTION OF VEHICLE SPEED FOR VARIOUS ENGINE GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Speed Coefficient	r^2	Std. Error	n
Pre-1970 Gas	5	366.707	-6.419±2.138	0.498**	186.353	28
	8	402.289				
	14	637.892				
	16	651.178				
1970-73 Gas	1	330.852	-6.568±1.321	0.802***	115.130	28
	3	334.461				
	9	412.244				
	12	768.615				
1974-75 Gas	2	407.875	-6.943±2.316	0.738***	100.590	56
	4	193.326	-2.384			
	6	170.703	-2.864			
	7	426.636	-6.673			
	10	548.050	-9.015			
	11	252.150	-3.595			
	13	352.905	-2.867			
	15	690.440	-12.096			
1975 Cal. Gas	17	93.079	-2.259±1.442	0.616**	88.866	14
	18	278.206				

Note:
1. Equation form: $Y = b_0 + b_1$ (speed)
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
   ** = 0.01
   *** = 0.001

TABLE 36. RESULTS OF REGRESSION ANALYSIS FOR NO$_x$ EMISSIONS AS A FUNCTION OF VEHICLE SPEED FOR VARIOUS ENGINE GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Speed Coefficient	r^2	Std. Error	n
Pre-1970 Gas	5	6.489	-0.002±0.061	0.716***	2.648	28
	8	2.578	0.326			
	14	5.750	-0.043			
	16	5.411	0.017			
1970-73 Gas	1	5.531	0.076±0.022	0.829***	1.935	28
	3	13.389				
	9	8.521				
	12	3.864				
1974-75 Gas	2	6.414	0.105±0.068	0.754***	2.953	56
	4	5.936	0.077			
	6	8.431	0.197			
	7	6.888	0.062			
	10	8.182	0.352			
	11	16.245	-0.035			
	13	18.126	-0.047			
	15	13.216	0.042			
1975 Cal. Gas	17	4.611	0.097±0.029	0.745***	1.793	14
	18	9.008				

Note:
1. Equation form: $Y = b_0 + b_1$ (speed)
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
   ** = 0.01
   *** = 0.001

TABLE 37. RESULTS OF RECRESSION ANALYSIS FOR FUEL CONSUMPTION AS A FUNCTION OF VEHICLE SPEED FOR VARIOUS ENGINE GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Speed Coefficient	r^2	Std. Error	n
Pre-1970 Gas	5	0.263	-0.004±0.001	0.683***	0.060	28
	8	0.290				
	14	0.397				
	16	0.355				
1970-73 Gas	1	0.214	-0.003±0.001	0.723***	0.049	28
	3	0.259				
	9	0.269				
	12	0.366				
1974-75 Gas	2	0.289	-0.004±0.001	0.623***	0.069	56
	4	0.262				
	6	0.291				
	7	0.330				
	10	0.356				
	11	0.200				
	13	0.349				
	15	0.383				
1975 Cal. Gas	17	0.249	-0.003±0.001	0.701**	0.054	14
	18	0.359				

Note: 1. Equation form: $Y = b_0 + b_1$ (speed)
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 38. RESULTS OF REGRESSION ANALYSIS FOR HC EMISSIONS AS A LOGARITHMIC FUNCTION OF SPEED FOR VARIOUS TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Spd. Coeff.	Spd. ^{2}Coeff.	r^2	Std. Error	n
Pre-1970 Gas	5	4.597	-0.153±0.026	0.0016±0.0004	0.838***	0.529	28
	8	5.533					
	14	5.258					
	16	5.314					
1970-73 Gas	1	3.486	-0.065±0.015	0.0004±0.0002	0.903***	0.312	28
	3	3.570					
	9	4.103					
	12	4.528					
1974-75 Gas	2	3.951	-0.096±0.012	0.0009±0.0002	0.856***	0.350	56
	4	4.015					
	6	4.348					
	7	4.088					
	10	4.527					
	11	4.050					
	13	4.171					
	15	4.509					
1975 Cal. Gas	17	3.015	-0.071±0.059	-0.003±0.0010	0.777***	0.856	14
	18	3.782					

Note: 1. Equation form $\ln(Y) = b_0 + b_1 (\text{speed}) + b_2 (\text{speed}^2)$
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 39. RESULTS OF REGRESSION ANALYSIS FOR CO EMISSIONS AS A LOGARITHMIC FUNCTION OF SPEED FOR VARIOUS TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Spd. Coeff.	Spd. ^{2} Coeff.	r^2	Std. Error	n
Pre-1970 Gas	5	6.690	-0.117±0.029	0.0015±0.0005	0.633***	0.602	28
	8	6.661					
	14	7.523					
	16	7.522					
1970-73 Gas	1	6.348	-0.097±0.024	0.0010±0.0004	0.805***	0.484	28
	3	6.263					
	9	6.705					
	12	7.799					
1974-75 Gas	2	6.519	-0.078±0.015	0.0008±0.0002	0.733***	0.439	56
	4	6.024					
	6	5.616					
	7	6.598					
	10	6.733					
	11	6.204					
	13	6.584					
	15	6.965					
1975 Cal. Gas	17	4.002	-0.037±0.064	0.0004±0.0011	0.567**	0.935	14
	18	5.722					

Note: 1. Equation form: $\ln(Y) = b_0 = b_1 (\text{speed}) + b_2 (\text{speed}^2)$
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 40. RESULTS OF REGRESSION ANALYSIS FOR NO_x EMISSIONS AS A LOGARITHMIC FUNCTION OF SPEED FOR VARIOUS TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Spd. Coeff.	Spd. ^{2}Coeff.	r^2	Std. Error	n
Pre-1970 Gas	5	1.369	0.042±0.023	-0.0007±0.0004	0.371*	0.465	28
	8	1.765					
	14	1.064					
	16	1.155					
1970-73 Gas	1	1.731	0.011±0.011	-0.0001±0.0002	0.803***	0.221	28
	3	2.503					
	9	2.122					
	12	1.505					
1974-75 Gas	2	2.062	-0.004±0.009	0.0002±0.0001	0.665***	0.255	56
	4	1.983					
	6	2.500					
	7	2.055					
	10	2.709					
	11	2.632					
	13	2.758					
	15	2.580					
1975 Cal. Gas	17	1.854	-0.010±0.014	0.0003±0.0002	0.766**	0.207	14
	18	2.385					

Note: 1. Equation form: $\ln(Y) = b_0 + b_1 (\text{speed}) + b_2 (\text{speed}^2)$
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 41. RESULTS OF REGRESSION ANALYSIS FOR FUEL CONSUMPTION AS A LOGARITHMIC FUNCTION OF SPEED FOR VARIOUS TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Spd. Coeff.	Spd. ^{2}Coeff.	r^2	Std. Error	n
Pre-1970 Gas	5	-0.953	-0.063±0.006	0.0008±0.0003	0.913***	0.133	28
	8	-0.833					
	14	-0.399					
	16	-0.553					
1970-73 Gas	1	-1.160	-0.061±0.007	0.0008±0.0001	0.902***	0.145	28
	3	-0.916					
	9	-0.875					
	12	-0.442					
1974-75 Gas	2	-0.621	-0.081±0.011	0.0011±0.0002	0.786***	0.326	56
	4	-0.736					
	6	-0.593					
	7	-0.425					
	10	-0.327					
	11	-1.679					
	13	-0.348					
	15	-0.259					
1975 Cal. Gas	17	-1.028	-0.057±0.008	0.0008±0.0001	0.931***	0.116	14
	18	-0.553					

Note: 1. Equation form: $\ln(Y) = b_0 + b_1 (\text{speed}) + b_2 (\text{speed}^2)$

2. Speed in miles per hour

3. Emissions in grams/miles

4. Significance: * = 0.05

** = 0.01

*** = 0.001

TABLE 42. AVERAGE EMISSIONS FROM THE 20 mph TRANSIENT CYCLE FOR GASOLINE TRUCKS TESTED UNDER CONTRACT 68-03-2147

	Empty Load, g/min			Half Load, g/min			Full Load, g/min		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
1974-1975 Gas	17.5	200.0	12.28	19.86	296.2	12.23	24.96	417.2	11.05
Pre-1970 Gas	20.28	352.9	5.47	25.18	278.8	4.91	29.07	572.0	4.91
1970-1973 Gas	15.62	254.2	9.14	20.16	353.5	9.43	29.86	378.3	9.54
1975 California Gas	9.24	148.2	8.19	10.41	192.3	9.19	11.21	266.0	9.73

> Weight/power ratio should be included as a covariate (this assumes that for all size trucks, the same deterioration rate holds). The same type of regression analysis should be performed for all trucks in data bases 1 and 2. SARR emission values should be used in these regressions.

The required regression analysis on these data bases was performed. The results are shown in Table 43. Only for fuel consumption is there more than one truck group where the regression is considered significant. Even for those regressions considered significant, the r^2 value indicates a good deal of data scatter. Considering that these were all in-service trucks with a wide variation in maintenance quality, the data scatter is probably not surprising.

Of more interest is the variation in value of the mileage coefficient of the various truck groups for a given emission specie and the negative coefficients for CO and fuel consumption. Negative coefficients for NO_x can be rationalized on the basis of decreased combustion efficiency with engine age.

For gasoline-powered trucks, the in-use surveillance project (EPA Contract 70-113),(19) may provide additional useful information on emission changes with mileage. In particular, Appendix F of the final report for that project may be helpful.

> Item 10-4 - For each of the model year groups within each of the three data bases, a regression should be performed with emissions as the dependent variable and test weight as the independent variable. Test weight/power ratio should be included as a covariate. The emissions will be the SARR emissions for data bases 1 and 2 and the 20 mph cycle for data base 3.
>
> The average test weight should be computed for vehicles in data bases 1 and 2. The average test weight for the empty, half load, and full load tests should be computed for each of the model year groups in data base 3 as well as for all gas trucks in data base 3.
>
> These regressions will later be normalized by EPA to the average test weight and average weight/power ratio built into the tabled emission values. These regressions will be able to predict the effects of changes in load (where load is the difference in average test weight).

The necessary regression analysis was performed on all data bases. The results are presented in Table 44. This table shows the regression coefficients for the relationship between each emission and vehicle weight and weight/CID. Within each emission a separate equation is shown for each level of emission control. For HC, CO, and fuel consumption, the majority of the truck groups had regression equations that were significant. In addition, the coefficients of determination are often above 0.600. It is probable that some of the data scatter in this analysis is due to the differences in emissions caused by ending model, as previously mentioned. However, for purposes of average truck populations, the present analysis should suffice.

TABLE 43. RESULTS OF REGRESSION ANALYSIS FOR EMISSIONS AND FUEL CONSUMPTION AS A FUNCTION OF MILEAGE AND WEIGHT/CID FOR VARIOUS TRUCK GROUPS

Group	Constant	Mileage/10000	Wt/CID	r^2	Std. Err.	No. of Trucks
		HC Emissions				
1. SARR Pre-1970 Gas	-8.508	2.376 ± 1.890	0.362 ± 0.789	0.196	31.088	10
2. SARR 1970-73 Gas	-18.958	2.264 ± 0.664	0.667 ± 0.153	0.606***	6.141	25
3. 1974-75 Gas	10.500	0.068 ± 2.752	0.152 ± 0.064	0.212	6.875	24
		CO Emissions				
1. SARR Pre-1970 Gas	233.308	-0.353 ± 2.673	0.179 ± 1.116	0.007	43.978	10
2. SARR 1970-73 Gas	-40.342	38.115 ±10.547	3.264 ± 2.428	0.420**	97.502	25
3. 1974-75 Gas	151.491	-105.687 ±46.937	4.917 ± 1.095	0.536	117.279	24
		NO_x Emissions				
1. SARR Pre-1970 Gas	-0.116	0.127 ± 0.160	0.111 ± 0.067	0.314	2.639	10
2. SARR 1970-73 Gas	9.107	-0.230 ± 0.436	0.042 ± 0.100	0.018	4.035	25
3. 1974-75 Gas	10.384	0.734 ± 1.176	0.015 ± 0.027	0.034	2.939	24
		Fuel Consumption				
1. SARR Pre-1970 Gas	0.065	0.002 ± 0.002	0.002 ± 0.001	0.611*	0.025	10
2. SARR 1970-73 Gas	0.052	0.010 ± 0.002	0.002 ± 0.001	0.635***	0.023	25
3. 1974-75 Gas	0.171	-0.012 ± 0.016	0.002 ± 0.000	0.438**	0.041	24

Notes:
1. Equation form: $y = b_0 + b_1$ (miles/1000) + b_2 (ratio)
2. Ratio = (weight/1000)/CID = (lb/1000)/in^3
3. Emissions in grams/mile
4. Significance:
   - * = 0.05
   - ** = 0.01
   - *** = 0.001
5. Group 1 - EPA Contract 68-03-0441
   Group 2 - EPA Contract EHS 70-113
   Group 3 - EPA Contract 68-03-2147

TABLE 44. RESULTS OF REGRESSION ANALYSIS FOR EMISSIONS AND FUEL CONSUMPTION AS A FUNCTION OF WEIGHT AND WEIGHT/CID FOR VARIOUS TRUCK GROUPS

Group	Constant	Wt/1000	Wt/CID	r^2	Std. Err.	No. of Trucks
HC Emissions						
1. SARR Pre-1970 Gas	43.477	5.927±7.000	-2.171±3.011	0.106	32.782	10
2. SARR 1970-73 Gas	-9.993	2.122±0.466	-0.165±0.236	0.689***	5.447	25
3. 1974-75 Gas	13.193	2.268±0.331	-0.809±0.145	0.757***	3.819	24
4. Pre-1970 Gas	28.098	3.534±1.070	-1.274±0.428	0.575*	7.766	12
5. 1970-73 Gas	0.516	0.853±0.569	0.039±0.231	0.717**	7.119	12
6. 1975 Calif. Gas	6.495	0.172±0.085		0.508	2.435	6
CO Emissions						
1. SARR Pre-1970 Gas	196.385	-8.736±8.801	3.804±3.786	0.127	41.217	10
2. SARR 1970-73 Gas	70.960	21.291±9.501	-4.754±4.814	0.247*	111.061	25
3. 1974-75 Gas	87.414	40.640±7.021	-12.423±3.070	0.778***	81.108	24
4. Pre-1970 Gas	171.235	22.845±9.797	-4.116±3.917	0.806***	71.090	12
5. 1970-73 Gas	212.014	43.937±5.593	-14.798±2.269	0.883***	69.943	12
6. 1975 Calif. Gas	9.708	8.814±2.239		0.795*	64.412	6
NO_x Emissions						
1. SARR Pre-1970 Gas	5.581	1.102±0.415	-0.349±0.179	0.628*	1.944	10
2. SARR 1970-73 Gas	9.250	0.168±0.345	-0.033±0.175	0.017	4.038	25
3. 1974-75 Gas	11.276	0.099±0.256	-0.026±0.112	0.023	2.956	24
4. Pre-1970 Gas	9.938	-0.083±0.319	-0.030±0.127	0.367	2.312	12
5. 1970-73 Gas	10.064	-0.486±0.311	0.167±0.126	0.224	3.988	12
6. 1975 Calif. Gas	6.597	0.111±0.028		0.799*	0.798	6
Fuel Consumption						
1. SARR Pre-1970 Gas	0.124	0.010±0.005	-0.002±0.002	0.703*	0.022	10
2. SARR 1970-73 Gas	0.093	0.010±0.002	-0.002±0.001	0.772***	0.018	25
3. 1974-75 Gas	0.175	0.014±0.002	-0.004±0.001	0.851***	0.021	24
4. Pre-1970 Gas	0.180	0.011±0.003	-0.003±0.001	0.800***	0.025	12
5. 1970-73 Gas	0.166	0.012±0.001	-0.004±0.001	0.909***	0.018	12
6. 1975 Calif. Gas	0.155	0.004±0.001		0.812*	0.026	6

Notes:
1. Equation form: $y = b_0 + b_1\ (\text{weight}/1000) + b_2\ \left((\text{wt}/1000)/\text{CID}\right)$
2. Weight in pounds and CID in cubic inches
3. Fuel consumption in gallons/mile
4. Significance: * = 0.05
   ** = 0.01
   *** = 0.001
5. Group 1 - EPA Contract 68-03-0441
   Group 2 - EPA Contract EHS 70-113
   Group 3 - EPA Contract 68-03-2147
   to 6

The average test weights for data bases 1 and 2 are shown in Table 31. The average test weight for the empty, half, and full load tests for each of the model year groups in data base 3 as well as the average test weight for all gasoline trucks in the data base are given in Table 45.

TABLE 45. AVERAGE TEST WEIGHTS FOR VARIOUS GASOLINE TRUCK GROUPS FROM CONTRACT 68-03-2147

	Test Weight, lb		
	Empty Load	Half Load	Full Load
Pre-1970 Gas	13752	21753	30255
1970-1973 Gas	12852	20654	29304
1974-1975 Gas	13568	21753	30005
1975 California Gas	12351	20254	28754
All Gas Trucks	13315	21342	29766
Average		21474	

IV. DIESEL TRUCK CYCLE ANALYSIS

This section covers the results of the analysis of 10 specific items requested by EPA. These items of analysis used the fuel consumption and emissions in grams/minute from the 12 diesel trucks tested by SwRI under Contract 68-03-2147, "Study of Emissions from Heavy-Duty Vehicles." A familiarity with the contents of the reports generated by that contract(13,14) is essential in understanding the analysis contained in this section. Other data bases were sometimes used to supplement this data. Each of the 10 items will be covered separately in the following paragraphs.

Item 1 - How well does test-to-test variability of a cycle compare with cycle-to-cycle variability for cycles of the same average speed? For all cycles?

The data from the two diesel-powered trucks (Nos. 24 and 25) that ran replicate tests were used to answer this question. An analysis of variance (ANOVA) was run for fuel rate, HC, CO, and NO_x for each of the three vehicle loads (empty, half, and full) tested. The steady-state, sinusoidal, and transient driving cycles were compared at common average speed designations of 5, 10, 15, 20, 30, and 40. These speed designations correspond to speeds of 8, 16, 24, 32, 48, and 64 kilometers per hour (kph), respectively. Only at 32 kph were all three types of cycles (steady-state, sinusoidal, and driving) available. At the other speeds, there were only two of the three cycle types available. The ANOVA was a partially nested analysis in that the replicates were nested within truck number.

Additional sources of variation in the data included effects due to replicates within each truck and truck by cycle interaction. The effects due to replicates within each truck were assumed to be random. If truck by cycle interaction was not significant, then truck by cycle sum of squares was pooled with that of the cycle by replication-within-truck interaction to increase the error degrees of freedom. The cycle by replication-within-truck interaction was assumed to be negligible to allow a test for significant difference between tests and for comparisons between test and driving cycle variability.

The results of the 72 tests (three emissions and fuel consumption at each of six speeds for three different loads) for significant differences between cycles and between tests-within-truck are given in Appendix C as Tables C-1 through C-4. From the indication of significance of the F ratio, it appears that, in general, the cycles differ significantly among themselves (except for the 64 kph cycles) while the tests show relatively no change. This is further supported by measurements of the estimated variability. The upper values in each table represent the estimated cycle variability, (MSC-MSE)/N*, while the lower numbers are the estimated test-to-test variability, (MSR(T)-MSE)/2. The truck by cycle interaction F ratio was checked for significance. Where not significant, the pooled MSE

---

*MSC - mean square cycle
MSE - mean square error
MSR(T) - mean square repeats within truck
N - sample size

was used in the calculations; where significant, the unpooled MSE was used. From an examination of the numeric values of the estimated variability, it is also evident that the cycle-to-cycle variability far exceeds the test-to-test variability.

The purpose of this analysis is to try and gain some indication of whether or not emission differences between different cycles at the same average speed are real or just the result of test-to-test variations. One way to determine this is to compare the significance of the F ratio from the test-to-test and cycle-to-cycle variations given in Appendix Tables C-1 through C-4. There are, of course, four possible combinations. The test-to-test variation can be not significant and the cycle-to-cycle variation can be either significant or not significant; or the test-to-test variation can be significant and the cycle-to-cycle variation can be either significant or not significant.

If the test-to-test variation is not significant, then the cycle-to-cycle variation can be evaluated with some degree of assurance that test-to-test variation is not unduly influencing the conclusions. If, however, the test-to-test variation is significant, the evaluation of emissions differences between cycles becomes more difficult. If the cycle-to-cycle variation is not significant, while the test-to-test variability is, then it is probably safe to conclude that there is no significant variation in that emission (or fuel consumption) between cycles. If the cycle-to-cycle variation is significant, then it is not possible to ascertain what part of the difference is due to test-to-test variability and what part is due to the cycle-to-cycle variation.

In the analysis of the diesel results, the 32 kph full load HC, the 24 kph empty load NO_x, the 8 kph empty load fuel, and the 64 kph full load fuel all had significant test-to-test variation. All of these except the 64 kph full load fuel had significant cycle-to-cycle variations as well. This fact should be kept in mind when using the analyses presented in this report.

In summary, it appears that for all but a few of the test cycles, test-to-test repeatability was not significant so that emission and fuel changes between cycles of the same speed can be evaluated. It should be pointed out in closing this discussion that the evaluation of the test-to-test variability was based on an absolute minimum of data (two replicate tests on two trucks). Thus, the results of this analysis should be used with care.

Item 2 - How well can fuel consumption and emissions measured by the present 13-mode FTP predict the fuel consumption and emissions over other cycles?

For this item, data from all 12 trucks were used. The first analysis done was to obtain a correlation matrix to determine the correlation between the 13-mode FTP fuel and emission rates (for composite 13-mode results as well as each individual mode) and the fuel and emission rates from the other driving cycles. This was done for each of the three vehicle test loads separately. Throughout the discussion of this item and the items that follow, it should be kept in mind that all emissions, whether modal, composite 13-mode, or a chassis dynamometer test cycle, are expressed in grams/minute since this was how the data was furnished from Contract 68-03-2147.

Tables 46, 47, and 48 show part of the results of this correlation matrix. Only correlations of like variables with correlation coefficients above 0.9 are shown and no correlations between modes of the 13-mode test are shown.

An examination of the tables shows that for the composite 13-mode emissions and fuel rate, only HC and NO_x correlated with any of the chassis dynamometer cycles. The composite HC emissions correlated with the higher speed steady-state HC emissions at empty load and the medium speed steady-state HC emission at half and full loads. The composite NO_x emissions correlated with an increasing number of cycles as load increased from empty to full. It is especially interesting to note that the 13-mode composite NO_x correlated with the full load 16, 24, and 32 kph transient driving cycle NO_x. The 13-mode composite NO_x emission is the only emission species that correlates with any of the transient driving cycles. The HC and NO_x emissions from the individual modes generally correlated with some of the dynamometer cycle emissions, while the CO and fuel rate only rarely correlated with the dynamometer cycle results. The modal emissions and fuel rate from the 100 percent power points at both speeds (modes 6 and 8) did not have correlation coefficients over 0.9 for any of the test cycles at any of the three loads. While individual variables for each mode will correlate with various test cycles, there is no one mode in which all of the emissions and fuel rate correlate with any of the test cycles.

Since the composite 13-mode emissions are normally of the most interest, Table 49 presents the correlation coefficients of the composite 13-mode emissions or fuel rate and the same variable from the other test cycles. For a complete description of the cycles, see Reference 13. A list of the different cycles used is included in Appendix A as Tables A-9 and A-10. As can be seen from the table, there is a strong, positive linear trend for all emissions except CO. However, except for the NO_x emissions from the transient driving cycles, only a few of the cycle emissions have correlation coefficients sufficiently large to use the 13-mode results to predict actual vehicle emissions. To help visualize the physical meaning of correlation coefficients on the order of 0.9, the NO_x emissions from the half load, 24 and 32 kph transient cycles are plotted as a function of the 13-mode composite NO_x emissions in Figure 20. It should be remembered that these relationships are for a specific group of trucks run on specific test cycles. Whether the relationships would generalize to all trucks and any cycle with the same average speed is not known. It should also be pointed out that the 13-mode emissions used are in grams/minute, not the usual grams/bhp-hr. With these facts in mind, however, it appears that 13-mode NO_x could be used to predict vehicle NO_x emissions under certain conditions.

A stepwise multiple regression analysis using a forward selection procedure was performed using emissions and fuel rate from each of the four transient driving cycles and 32 and 48 kph sinusoidal cycle as functions of the modal emissions and fuel rate from the 13-mode test. The significance levels for both inclusion or exclusion of the modes were set at 0.05. In this analysis, a zero intercept was assumed, but the modal coefficients (weighting factors) were not constrained to be positive nor were they constrained to sum to 1.0. The analysis showed that many of the modal emissions and fuel rate were highly correlated with other modes, particularly for fuel rate. This does not mean that some of the modes are not important, only that for this particular set of 12 trucks, some of the

TABLE 46. DIESEL TRUCK VARIABLES HAVING CORRELATION COEFFICIENTS GREATER THAN 0.9 FOR EMPTY LOAD TESTS

EMPTY LOAD

I. Composite 13-Mode

Correlates with:

HC	CO	NO_x	Fuel Rate
30 S/S HC		55 S/S HC	
40 S/S HC			
55 S/S HC			
40 sine HC			

II. Modes 1, 7, 13 (Idle)

Correlates with:

HC	CO	NO_x	Fuel Rate
Idle S/S HC	Idle S/S CO	Idle S/S NO_x	Idle S/S Fuel
	55 S/S CO	5 S/S NO_x	
		10 S/S NO_x	
		15 S/S NO_x	
		5 Avg. NO_x	
		10 Avg. NO_x	
		15 Avg. NO_x	

III. Mode 2

Correlates with:

HC	CO	NO_x	Fuel Rate
15 S/S HC		All NO_x except idle S/S	
20 S/S HC			
30 sine HC			

IV. Mode 3

Correlates with:

HC	CO	NO_x	Fuel Rate
30 S/S HC		All except Idle S/S and 5 S/S	
40 S/S HC			
55 S/S HC			
40 sine HC			

V. Mode 4

Correlates with:

HC	CO	NO_x	Fuel Rate
30 S/S HC		20 S/S NO_x	
40 S/S HC		30 S/S NO_x	
55 S/S HC		40 S/S NO_x	
40 sine HC		55 S/S NO_x	
		10 Avg. NO_x	
		15 Avg. NOx	
		20 Avg. NO_x	

VI. Mode 5

Correlates with:

HC	CO	NO_x	Fuel Rate
55 S/S HC		55 S/S NO_x	
		10 Avg. NO_x	
		20 Avg. NO_x	

TABLE 4b(cont'd). DIESEL TRUCK VARIABLES HAVING CORRELATION COEFFICIENTS GREATER THAN 0.9 FOR EMPTY LOAD TESTS

VII. Mode 6

HC	CO	NO_x	Fuel Rate
Correlates with none of the cycles			

VIII. Mode 8

HC	CO	NO_x	Fuel Rate
Correlates with none of the cycles			

IX. Mode 9

HC	CO	NO_x	Fuel Rate
Correlates with:			
40 S/S HC 55 S/S HC		55 S/S NO_x	

X. Mode 10

HC	CO	NO_x	Fuel Rate
Correlates with:			
30 S/S HC 40 S/S HC 55 S/S HC 40 sine HC		55 S/S NO_x	

XI. Mode 11

HC	CO	NO_x	Fuel Rate
Correlates with:			
30 S/S HC		All except Idle S/S, 5 S/S and 10 S/S NO_x	

XII. Mode 12

HC	CO	NO_x	Fuel Rate
Correlates with:			
30 S/S HC 40 S/S HC 40 sine HC		All , except Idle S/S and 5 S/S NO_x	

TABLE 47. DIESEL TRUCK RELATIONSHIPS BETWEEN MODAL AND CHASSIS DYNAMOMETER CYCLE EMISSIONS HAVING CORRELATION COEFFICIENTS GREATER THAN 0.9 FOR HALF LOAD TESTS

Sample Size: Twelve diesel trucks

HALF LOAD

I. Composite 13-Mode

HC	CO	NO_x	Fuel Rate
	Correlation with:		
30 S/S HC		55 S/S NO_x	
40 S/S HC		5 Avg. NO_x	
40 sine HC		10 Avg. NO_x	
		15 Avg. NO_x	
		20 Avg. NO_x	

II. Modes 1, 7, 13 (Idle)

HC	CO	NO_x	Fuel Rate
	Correlates with:		
Idle S/S HC	Idle S/S CO	Idle S/S NO_x	Idle S/S Fuel
		5 S/S NO_x	20 S/S Fuel
		15 S/S NO_x	

III. Mode 2

HC	CO	NO_x	Fuel Rate
	Correlates with:		
10 S/S HC		All NO_x, except	
15 S/S HC		Idle S/S, 15 Avg.	
20 S/S HC		and 20 Avg. NO_x	

IV. Mode 3

HC	CO	NO_x	Fuel Rate
	Correlates with:		
30 S/S HC		All NO_x, except	40 S/S Fuel
40 S/S HC		idle SS, 5 S/S	
40 sine HC		and 10 S/S NO_x	

V. Mode 4

HC	CO	NO_x	Fuel Rate
	Correlates with:		
30 S/S HC		40 S/S NO_x	
40 S/S HC		55 S/S NO_x	
40 sine HC		20 sine NO_x	
		30 sine NO_x	
		40 sine NO_x	
		5 Avg. NO_x	
		10 Avg. NO_x	
		15 Avg. NO_x	
		20 Avg. NO_x	

VI. Mode 5

HC	CO	NO_x	Fuel Rate
	Correlates with:		
55 S/S HC		55 S/S NO_x	
40 sine HC		20 sine NO_x	
		30 sine NO_x	
		5 Avg. NO_x	
		15 Avg. NO_x	
		20 Avg. NO_x	

TABLE 47 (Cont'd). DIESEL TRUCK RELATIONSHIPS BETWEEN MODAL AND CHASSIS DYNAMOMETER CYCLE EMISSIONS HAVING CORRELATION COEFFICIENTS GREATER THAN 0.9 FOR HALF LOAD TESTS

Sample Size: Twelve diesel trucks

VII. Mode 6

HC	CO	NO_x	Fuel Rate
Correlates with none of the cycles			

VIII. Mode 8

HC	CO	NO_x	Fuel Rate
Correlates with none of the cycles			

IX. Mode 9

HC	CO	NO_x	Fuel Rate
Correlates with:			
40 sine HC		55 S/S NO_x	
		20 sine NO_x	
		30 sine NO_x	
		5 Avg. NO_x	
		10 Avg. NO_x	
		15 Avg. NO_x	
		20 Avg. NO_x	

X. Mode 10

HC	CO	NO_x	Fuel Rate
Correlates with:			
30 S/S HC	40 sine CO	55 S/S NO_x	
40 S/S HC		20 sine NO_x	
40 sine HC			

XI. Mode 11

HC	CO	NO_x	Fuel Rate
Correlates with:			
30 S/S HC	20 S/S CO	20 S/S NO_x	
		30 S/S NO_x	
		40 S/S NO_x	
		55 S/S NO_x	
		20 sine NO_x	
		30 sine NO_x	
		40 sine NO_x	
		5 Avg. NO_x	
		15 Avg. NO_x	

XII. Mode 12

HC	CO	NO_x	Fuel Rate
Correlates with:			
20 S/S HC	20 S/S CO	15 S/S NO_x	
40 S/S HC		20 S/S NO_x	
		30 S/S NO_x	
		40 S/S NO_x	
		55 S/S NO_x	
		20 sine NO_x	
		30 sine NO_x	
		40 sine NO_x	

TABLE 48. DIESEL TRUCK RELATIONSHIPS BETWEEN MODAL AND CHASSIS DYNAMOMETER CYCLE EMISSIONS HAVING CORRELATION COEFFICIENTS GREATER THAN 0.9 FOR FULL LOAD TESTS

Sample Size: Twelve diesel trucks

FULL LOAD

I. Composite 13-Mode

HC	CO	NO_x	Fuel Rate
Correlates with:			
30 S/S HC		55 S/S NO_x	
40 S/S HC		20 sine NO_x	
40 sine HC		30 sine NO_x	
		10 Avg. NO_x	
		15 Avg. NO_x	
		20 Avg. NO_x	

II. Modes 1, 7, 13 (Idle)

HC	CO	NO_x	Fuel Rate
Correlates with:			
Idle S/S HC	Idle S/S CO	Idle S/S NO_x	Idle S/S Fuel
		15 S/S NO_x	20 S/S Fuel
			10 Avg. Fuel

III. Mode 2

HC	CO	NO_x	Fuel Rate
Correlates with:			
10 S/S HC		5 S/S NO_x	
20 S/S HC		10 S/S NO_x	
30 S/S HC		15 S/S NO_x	
		20 S/S NO_x	
		30 S/S NO_x	
		40 S/S NO_x	
		40 sine NO_x	

IV. Mode 3

HC	CO	NO_x	Fuel Rate
Correlates with:			
30 S/S HC		10 S/S NO_x	
40 S/S HC		15 S/S NO_x	
		20 S/S NO_x	
		30 S/S NO_x	
		40 S/S NO_x	
		55 S/S NO_x	

V. Mode 4

HC	CO	NO_x	Fuel Rate
Correlates with:			
30 S/S HC		30 S/S NO_x	
40 S/S HC		40 S/S NO_x	
		40 sine NO_x	

TABLE 46. (Cont'd) DIESEL TRUCK RELATIONSHIPS BETWEEN MODAL AND CHASSIS DYNAMOMETER CYCLE EMISSIONS HAVING CORRELATION COEFFICIENTS GREATER THAN 0.9 FOR FULL LOAD TESTS

Sample Size: Twelve diesel trucks

VI. Mode 5

HC	CO	NO_x	Fuel Rate
	Correlates with:		
40 sine HC		55 S/S NO_x	40 sine Fuel
		20 sine NO_x	
		30 sine NO_x	
		40 sine NO_x	
		5 Avg. NO_x	
		10 Avg. NO_x	
		15 Avg. NO_x	
		20 Avg. NO_x	

VII. Mode 6

HC	CO	NO_x	Fuel Rate
	Correlates with none of the cycles		

VIII. Mode 8

HC	CO	NO_x	Fuel Rate
	Correlates with:		
		55 S/S NO_x	

IX. Mode 9

HC	CO	NO_x	Fuel Rate
	Correlates with:		
30 S/S HC	40 sine CO	55 S/S NO_x	
40 S/S HC		20 sine NO_x	
40 sine HC		30 sine NO_x	
		10 Avg. NO_x	
		5 Avg. NO_x	
		20 Avg. NO_x	

X. Mode 10

HC	CO	NO_x	Fuel Rate
	Correlates with:		
30 S/S HC	40 S/S CO	30 S/S NO_x	
40 S/S HC			

XI. Mode 11

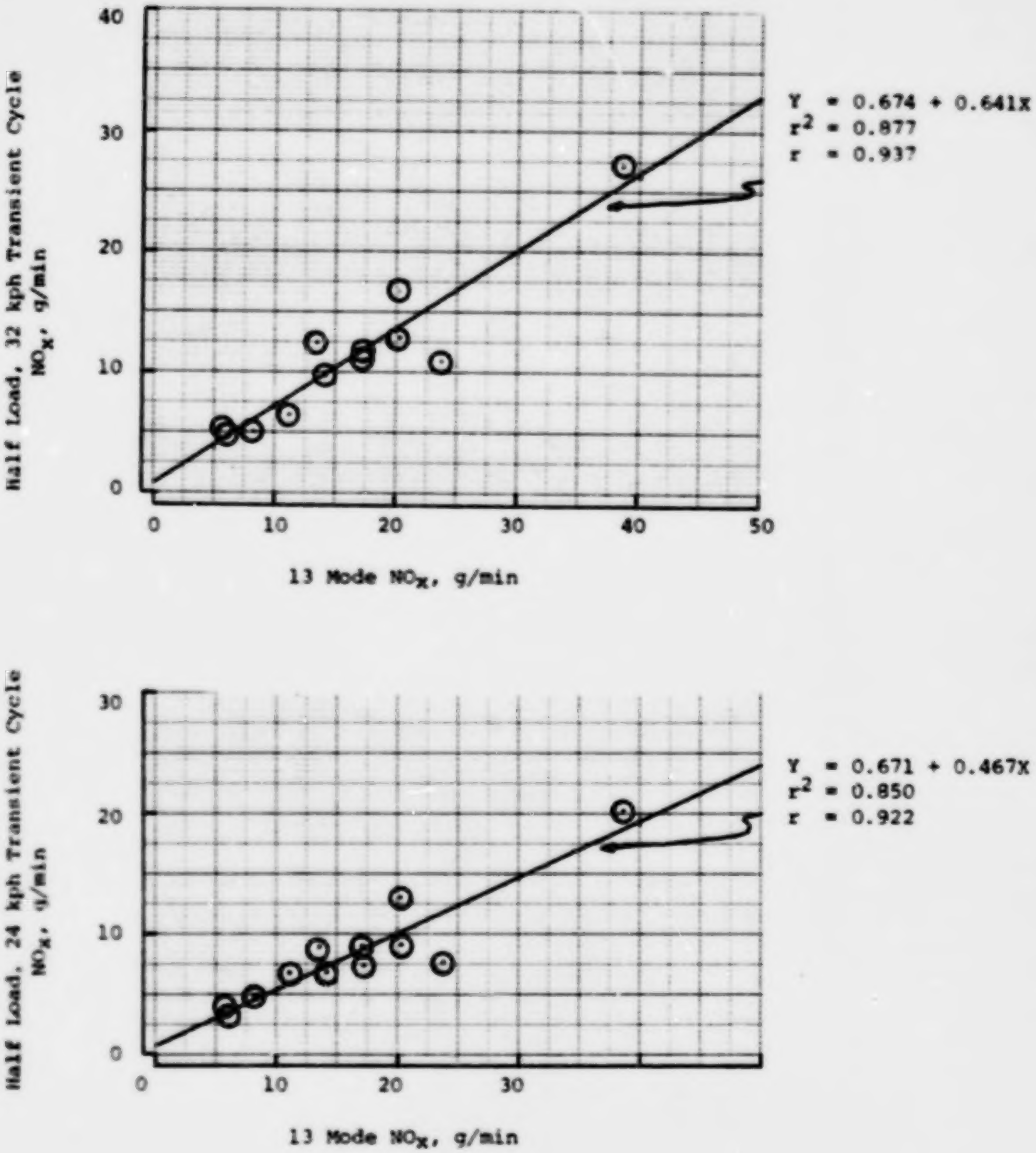
HC	CO	NO_x	Fuel Rate
	Correlates with:		
30 S/S HC	20 S/S CO	5 S/S NO_x	
		15 S/S NO_x	
		20 S/S NO_x	
		30 S/S NO_x	
		40 S/S NO_x	
		40 sine NO_x	

XII. Mode 12

HC	CO	NO_x	Fuel Rate
	Correlates with:		
20 S/S HC		5 S/S NO_x	
30 S/S HC		10 S/S NO_x	
40 S/S HC		15 S/S NO_x	
		20 S/S NO_x	
		30 S/S NO_x	
		40 S/S NO_x	

TABLE 49. CORRELATION COEFFICIENTS FROM BETWEEN 13-MODE FTP RESULTS AND DYNAMOMETER TEST CYCLE RESULTS FOR 12 DIESEL TRUCKS

Test	Empty Load				Half Load				Full Load			
Desc.	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel
00 SS	0.580	0.137	0.550	0.716	0.614	0.342	0.404	0.651	0.653	0.308	0.508	0.642
05 SS	0.777	0.361	0.791	0.516	0.796	0.517	0.779	0.535	0.823	0.450	0.811	0.557
10 SS	0.618	0.294	0.799	0.604	0.682	0.369	0.788	0.654	0.763	0.361	0.812	0.657
15 SS	0.703	0.228	0.800	0.649	0.818	0.182	0.784	0.678	0.831	0.163	0.788	0.645
20 SS	0.778	0.113	0.833	0.744	0.849	-0.028	0.813	0.765	0.857	0.090	0.822	0.742
30 SS	0.934	-0.194	0.844	0.768	0.945	-0.120	0.851	0.829	0.955	0.002	0.881	0.833
40 SS	0.952	-0.143	0.842	0.857	0.967	-0.059	0.845	0.884	0.945	0.166	0.865	0.873
55 SS	0.920	0.139	0.915	0.797	0.787	0.483	0.950	0.850	0.668	0.744	0.934	0.858
20 ± 5	0.751	0.359	0.846	0.614	0.552	0.916	0.917	0.785	0.325	0.743	0.921	0.780
30 ± 5	0.690	0.382	0.863	0.794	0.533	0.327	0.889	0.798	0.481	0.800	0.929	0.824
40 ± 2	0.938	0.050	0.837	0.355	0.818	-0.093	0.841	0.854	0.902	0.402	0.884	0.878
05 Avg.	0.638	0.596	0.851	0.685	0.754	0.439	0.905	0.862	0.591	0.669	0.882	0.787
10 Avg.	0.638	0.490	0.885	0.806	0.733	0.632	0.917	0.847	0.536	0.736	0.918	0.803
15 Avg.	0.600	0.548	0.872	0.769	0.663	0.733	0.922	0.867	0.668	0.831	0.918	0.825
20 Avg.	0.676	0.518	0.885	0.771	0.702	0.716	0.937	0.875	0.590	0.810	0.917	0.828



$Y = 0.674 + 0.641X$
$r^2 = 0.877$
$r = 0.937$

$Y = 0.671 + 0.467X$
$r^2 = 0.850$
$r = 0.922$

FIGURE 20. NO$_x$ EMISSIONS FROM TWO HALF LOAD TRANSIENT CYCLES AS FUNCTIONS OF 13-MODE NO$_x$ EMISSIONS IN GRAMS PER MINUTE

modal emissions (or fuel rate) are a multiple (possibly plus a constant) of other modes. With a different set of trucks, these correlations could change. The correlation coefficients between modes are shown in Table 50.

The modal regression coefficients relating the modal emissions and fuel rate to various dynamometer cycle emissions and fuel rate are contained in Tables C-5 to C-8 of Appendix C. The coefficients are shown to the 0.05 significance level. Generally this required two modes, although sometimes one and sometimes three modes were used. The coefficients of determination (r^2) given in Tables C-5 to C-8 should not, in general, be directly compared with the correlation coefficients (r) given in Table 49. The correlation coefficients in Table 49 reflect the correlation between one independent variable (13-mode composite emission or fuel rate) and one dependent variable (dynamometer cycle emission or fuel rate). The coefficients of determination in Tables C-5 to C-8 on the other hand, generally reflect the correlation between two or more independent variables, and one dependent variable.

To obtain correlation coefficients from the stepwise regressions to compare with Table 49, the composite emissions of fuel rate would have to be calculated using the coefficients in Tables C-5 to C-8 and a regression performed using the composite emission and the driving cycle emission. Of course, where only one mode was used in the stepwise regression, it is the composite value and the square root of its coefficient of determination can be compared with the corresponding correlation coefficient in Table 49.

From an engineering standpoint, there are many problems with using only one or two discrete points of engine operation to predict the emissions and fuel rate when the engine is operating in a vehicle over a wide range of speed and power. First, the data represents only 12 trucks operating at certain vehicle weight and vehicle weight to engine power ratios. Other trucks, vehicle weights and weight/power ratios could have different relationships. Secondly, the relationship between one engine operating point and other operating points is very much subject to change as emission regulations and fuel economy pressures cause changes in engine design and scheduling of the fuel injection system. For these reasons a table similar to Table 49 was not prepared for the stepwise regression results.

The stepwise regression results can be used to determine which of the modes are most important in predicting emissions and fuel rate from test cycles by examining the order in which the mode was entered in the regression analysis. Table 51 shows the order that each mode was entered for each emission type and each test cycle. For each emission type there was one mode which generally, though not always, entered first. For HC emissions, Mode 2 generally entered first. For CO emissions, Modes 8 and 10 were entered first most often. For NO_x, Mode 2 was entered first for the empty load tests, while Mode 5 was generally entered first for the half and full load tests. For fuel rate, only for the empty load tests had one mode, idle, that was generally entered first.

To determine if the 13 modes could be reweighted to obtain a new set of composite values which would better correlate to driving cycles, with the constraints that the weighting factors be positive and that they sum to 1.0, a special analysis was performed. Linear programming techniques were used to obtain modal coefficients that were constrained to be positive and sum to 1.0. The computer program used was based on Lemke's

TABLE 50. CORRELATION COEFFICIENTS BETWEEN MODES OF THE 13-MODE DIESEL HEAVY DUTY FTP

	Idle	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 8	Mode 9	Mode 10	Mode 11	Mode 12
						HC EMISSIONS					
Idle	1.000	0.918	0.943	0.925	0.832	0.703	0.853	0.879	0.918	0.935	0.917
Mode 2		1.000	0.966	0.955	0.916	0.740	0.863	0.933	0.953	0.943	0.973
Mode 3			1.000	0.992	0.953	0.784	0.917	0.978	0.987	0.986	0.985
Mode 4				1.000	0.971	0.795	0.903	0.976	0.987	0.973	0.970
Mode 5					1.000	0.867	0.913	0.970	0.955	0.923	0.927
Mode 6						1.000	0.911	0.837	0.793	0.768	0.748
Mode 8							1.000	0.932	0.912	0.917	0.888
Mode 9								1.000	0.989	0.980	0.975
Mode 10									1.000	0.992	0.984
Mode 11										1.000	0.987
Mode 12											1.000
						CO EMISSIONS					
Idle	1.000	0.874	0.681	0.761	0.889	0.638	0.602	0.721	0.857	0.747	0.704
Mode 2		1.000	0.910	0.904	0.849	0.670	0.695	0.855	0.930	0.928	0.924
Mode 3			1.000	0.948	0.676	0.690	0.710	0.774	0.867	0.948	0.969
Mode 4				1.000	0.806	0.672	0.704	0.822	0.931	0.937	0.931
Mode 5					1.000	0.603	0.670	0.869	0.851	0.713	0.671
Mode 6						1.000	0.839	0.601	0.581	0.559	0.591
Mode 8							1.000	0.803	0.698	0.665	0.682
Mode 9								1.000	0.892	0.818	0.793
Mode 10									1.000	0.951	0.914
Mode 11										1.000	0.990
Mode 12											1.000
						NO_x EMISSIONS					
Idle	1.000	0.912	0.877	0.890	0.910	0.861	0.899	0.894	0.866	0.866	0.876
Mode 2		1.000	0.985	0.963	0.944	0.822	0.871	0.936	0.944	0.966	0.980
Mode 3			1.000	0.983	0.957	0.829	0.890	0.956	0.964	0.975	0.969
Mode 4				1.000	0.989	0.894	0.940	0.982	0.981	0.973	0.962
Mode 5					1.000	0.941	0.974	0.992	0.981	0.962	0.955
Mode 6						1.000	0.984	0.930	0.897	0.840	0.855
Mode 8							1.000	0.971	0.941	0.895	0.891
Mode 9								1.000	0.993	0.973	0.959
Mode 10									1.000	0.989	0.973
Mode 11										1.000	0.988
Mode 12											1.000
						FUEL RATE					
Idle	1.000	0.985	0.979	0.979	0.983	0.985	0.986	0.986	0.986	0.991	0.989
Mode 2		1.000	0.988	0.985	0.987	0.990	0.987	0.985	0.985	0.990	0.989
Mode 3			1.000	0.999	0.998	0.998	0.998	0.997	0.997	0.994	0.978
Mode 4				1.000	0.999	0.998	0.999	0.998	0.998	0.993	0.977
Mode 5					1.000	0.999	0.998	0.997	0.997	0.994	0.980
Mode 6						1.000	0.998	0.996	0.996	0.993	0.981
Mode 8							1.000	0.999	0.999	0.996	0.982
Mode 9								1.000	1.000	0.997	0.983
Mode 10									1.000	0.997	0.985
Mode 11										1.000	0.991
Mode 12											1.000

Sample Size: 12 diesel trucks

TABLE 51. ORDER OF ENTRY IN STEPWISE MULTIPLE REGRESSION OF INDIVIDUAL MODES OF THE DIESEL HEAVY-DUTY 13-MODE FTP FOR 12 DIESEL TRUCKS

Test Cycle		Idle	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 8	Mode 9	Mode 10	Mode 11	Mode 12
						HC Emissions						
						Empty Load						
Sinusoidal	20	2	1	7	5	4	9	3	10	6	8	--
	30	10	1	9	8	7	3	2	5	4	6	--
Transient	10	2	1	9	5	4	8	6	10	7	--	3
	15	2	1	11	6	7	8	12	4,R10*,13	9	5	3
	20	4	1	10	5,R12*	2	6	9	11	7	8	3
						Half Load						
Sinusoidal	20	5	1,R9*,12	3	7	10	11	13	6	8	4	2
	30	4	1	--	10	9	8	6	7	3	5	2
Transient	10	3	1,R10*,12	7	5	2	6	11	13	8	4	9
	15	6	1	4,R10*,13	8	9	2	14	7	11	5	3,R12*
	20	4	2	--	5	1	6	7	--	8	--	3
						Full Load						
Sinusoidal	20	4	1	3	8	9	11	10	6	12	5	2,R7*
	30	7	1	4	5	6	3,R10*	8	11	9	--	2
Transient	10	8	1	4,R11*,14	5	9	2,R7*,10	16	6R13*,17	12	15	3
	15	7	1	4,R12*	5	9	2,R8*,10	13	6	11	--	3
	20	2	6	5,R9*,12	3	1	4	10	11	7	8	--

Test Cycle		Idle	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 8	Mode 9	Mode 10	Mode 11	Mode 12
						CO Emissions						
						Empty Load						
Sinusoidal	20	5	11	9	3	6	2	4	8	1	7	10
	30	6	7	11	1	9	10	2	4	8	3	5
Transien.	10	10	8	7	3	2	3	5	6	1	--	4
	15	8	7	9	6	10	2	4	5	1	11	3
	20	6	5	9	11	1	10	3	4	3	8	7
						Half Load						
Sinusoidal	20	2,R6*,15	16	12	11	3	5,R9*,12	14	4	1	7	8
	30	--	8	9	7	2	6	1	--	1	3	4
Transient	10	3	7	9	4	1	6	2	10	11	3	8
	15	4	7	8	3	1	9	2	--	6	10	5
	20	10 .	4	9	8	2	3	1	6	5	11	7
						Full Load						
Sinusoidal	20	5	4	10	7	2	11	1	3	9	8	6
	30	5	6	4,R12*	10	2	11	1	3	7	9	8
Transient	10	6	7	--	3	2	--	1	4	5	9	8
	15	7	12	4,R11*,12	3	2	5	1	8	9	6	10
	20	7	4	10	9	2	11	1	8	3	6	5

---

* R means removed

TABLE 51 (cont'd). ORDER OF ENTRY IN STEPWISE MULTIPLE REGRESSION OF INDIVIDUAL MODES OF THE DIESEL HEAVY-DUTY 13-MODE FTP FOR 12 DIESEL TRUCKS

Test Cycle		Idle	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 8	Mode 9	Mode 10	Mode 11	Mode 12
						NO_x Emissions						
						Empty Load						
Sinusoidal	20	7	1,R10*	3	8	9	4	2	--	6	--	5
	30	3	1	9	7	8	5	--	2	6	--	4
Transient	10	7	1	4	6	5	3	2	--	--	9	8
	15	3	1	7	10	9	8	2	4	5	--	6
	20	9	1	4	6,R10*	5	3	2	--	8	--	7
						Half Load						
Sinusoidal	20	2,R7*,10	6	11	13	5,R14*,16	15	9	3	4	1,R12*	8
	30	2	5	3	10	--	9	8	7	6	1	4
Transient	10	2	7	3	4	1	5	6	--	8	--	9
	15	2	9	10	8	1	3	7	4	5	6	--
	20	2	--	3	4	1	9	--	6	5	8	7
						Full Load						
Sinusoidal	20	2	--	10	7	8	5	--	1	3	4,R9*	6
	30	2	10	9	6	1	8	7	3	4	5	--
Transient	10	2	--	5	4	1	6	9	8	--	7	3
	15	2	4	--	3	1	5	6	--	7	--	8
	20	2	--	4	3	1	10	9	6	5	7	8

Test Cycle		Idle	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 8	Mode 9	Mode 10	Mode 11	Mode 12
						Fuel Consumption						
						Empty Load						
Sinusoidal	20	1	2	--	--	8	5	4	6	--	3	7
	30	4	1,R5*,9	2	3	--	7	--	--	6	10	8
Transient	10	2	5	4	--	7	1,R6*,9	--	--	3	10	8
	15	1	8	2	3	--	6	5	--	--	8	7
	20	1	6	2	3	--	7	--	--	--	8	5
						Half Load						
Sinusoidal	20	4	--	--	2	--	5	1	3	--	7	6
	30	2	6	1	--	8	4	--	--	3	7	5
Transient	10	2	6	4	5	--	1	--	--	--	3	7
	15	2	5	3	--	--	1	--	4	--	7	6
	20	2	5	3	--	10	9	1,R6*	--	4	8	7
						Full Load						
Sinusoidal	20	3	8	--	4	--	5	1	2	--	7	6
	30	5	7	1	2,R9*	3	4	--	--	6	10	9
Transient	10	2	6	4	--	8	1	--	5	--	3	7
	15	2	6	4	--	9	1,R5*,10	--	3	--	8	7
	20	4	7	3	2	1	6	--	--	--	5	--

---

* R means removed

complementary pivot method to solve the quadratic minimization of $\Sigma(y-\hat{y})^2$. The actual computer algorithm was obtained from Reference 17. A Fortran listing of the program used is included in Appendix A.

In this case, "y" is chassis dynamometer test cycle measured emission or fuel consumption and "$\hat{y}$" is the calculated reweighted 13-mode composite emission or fuel consumption. Note that this method causes the chassis dynamometer test cycle results and 13-mode results to try to obtain numerical equivalency. In other words, if $\Sigma(y-\hat{y})^2$ equals zero, then a straight line relating $\hat{y}$ to y would have a slope of 1.0. The form of the equation generated to obtain the new weighting factors is:

$$Y = AX_1 + BX_2 + CX_3 + DX_4 + EX_5 + FX_6$$

where Y is driving cycle HC, CO, NO_x or fuel rate.

X_1, X_2, X_3, etc. are individual modal values of HC, CO, NO_x or fuel rate.

A, B, C, etc. are the regression coefficients for the individual modes.

It should be noted that while the diesel heavy-duty emission test has 13 modes, modes 1, 7, and 13 are all at idle. These modes have been combined for this analysis, giving 11 separate modes. Note that a zero intercept was assumed. Also, it should be pointed out that if an unconstrained regression analysis results in any coefficients that are negative, a regression analysis which constrains the coefficients to be positive will have at least one zero coefficient.$^{(21)}$ The equation coefficients are the modal weighting factors, except for the idle mode where the coefficient must be divided by three. There is a separate equation for each driving cycle and load for each emission or fuel rate.

The regression coefficients and coefficients of determination for the 60 equations obtained are contained in Appendix C as Tables C-9 through C-12. It should be clearly understood that the coefficients of determination listed with the regression coefficients are not the coefficients of determination for a linear fit of the observed driving cycle to calculated composite 13-mode emissions. Rather, the coefficients of determination reflects the fit of the driving cycle value to the 11 different modal values from the 13-mode test.

It can be seen from the tables that except for NO_x, modes 3, 9, and 11 generally had a zero weighting factor regardless of emission, load, cycle or speed. Except for CO, modes 4 and 10 generally had a zero weighting factor. This means that for HC and fuel rate, five of the eleven different modes had zero for a weighting factor.

In order to obtain a better understanding of the usefulness of the new weighting factors, a linear regression was performed on the composite 13-mode results using the new weighting factors and the emissions or fuel consumption from the respective driving cycles. The correlation coefficients are shown in Table 52.

TABLE 52. CORRELATION COEFFICIENTS FROM REGRESSION ANALYSIS BETWEEN REWEIGHTED 13-MODE RESULTS AND DRIVING CYCLE RESULTS FOR TWELVE DIESEL TRUCKS

Test	Empty Load				Half Load				Full Load			
Desc.	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel	HC	CO	NO_x	Fuel
20 ± 5	0.897	0.959	0.946	0.689	0.777	0.953	0.970	0.834	0.634	0.846	0.948	0.824
30 ± 5	0.883	0.979	0.957	0.860	0.822	0.946	0.956	0.843	0.694	0.896	0.949	0.858
10 Avg.	0.808	0.948	0.983	0.868	0.858	0.927	0.970	0.892	0.692	0.939	0.958	0.848
15 Avg.	0.743	0.901	0.975	0.830	0.810	0.955	0.964	0.897	0.791	0.959	0.942	0.858
20 Avg.	0.826	0.899	0.973	0.823	0.869	0.894	0.969	0.903	0.723	0.934	0.941	0.863

Comparing the correlation coefficients using the FTP weighting factors in Table 49 and those using the recalculated weighting factors in Table 52, it can be seen that in all cases, the recalculated weighting factors produce a better fit than the FTP weighting factors. In general, the reweighted 13-mode correlations are not felt to be good enough to use the reweighted 13-mode emissions and fuel rate to predict driving cycle emissions and fuel rate. The exception is NO_x emissions, where the reweighted correlations may be high enough to use the reweighted NO_x as a predictor for driving cycle NO_x.

The linear programming techniques used to reweight the modes were necessitated by the two constraints on the weighting factors requested by the EPA. One constraint was the weighting factors (which are the coefficients in the equation) must all be positive; the other was that the weighting factors sum to 1.0. As a consequence of the least squares method, the method necessarily tried to generate modal coefficients that would produce composite emission or fuel rate identically equal to the dynamometer test emission or fuel rate. In other words, an equation relating 13-mode and dynamometer test cycle emissions or fuel rate would have a slope of 1.0. However, it is not really necessary that the composite 13-mode value be equal to the dynamometer test cycle value, only that it can predict the test cycle value. It was then realized that the constraint requiring the modal coefficients sum to 1.0 is an unnecessary constraint.

It is possible to make any group of coefficients sum to 1.0 simply by summing the coefficients and dividing each coefficient and the dependent variable (y) by the sum. To be sure, this changes the absolute value of the composite emission (or fuel rate); but it does not change the correlation coefficient of the equation. Rather than develop a new program including the two restraints, to generate an optimum set of weighting factors, there is another way to obtain the best possible correlation between composite modal values and dynamometer test cycle values. This is to use a nonlinear regression analysis such as found in the UCLA BMD statistical program which allows all of coefficients to be constrained to positive values. Then recalculate the coefficients (and the composite values) by dividing each of the coefficients and the composite value by the sum of the coefficients. It should be emphasized that the linear programming technique used to generate the reweighted values contained in this section is not incorrect, it is simply overly restrictive since a regression with one constraint will give a better fit than a regression with two constraints.

Since it was also requested that one set of weighting factors be obtained using all emissions and fuel rate as if they were one variable, it was decided to use the method outlined in the above paragraph to obtain this set of weighting factors. The coefficients constrained to be positive for each test cycle are given in Appendix C as Tables C-13, the regression coefficients normalized to sum to 1.0 are contained in Table C-14.

In ending the discussion on this item, it should be pointed out that it may also be possible to obtain a better correlation of the 13-mode emissions or fuel consumption and driving cycle emissions or fuel consumption if the engine power/vehicle weight ratio relationship to emissions were fully explored and accounted for. However, the effort allotted to this item does not permit exploration of these possibilities.

Item 3 - Item 3 applied to the gasoline-powered trucks but not to the diesel-powered trucks. It is mentioned here merely to keep the item numbers consistent between the gasoline and diesel truck analyses.

Item 4 - How does the percent change in fuel rate and emissions for various levels of control measured over the 13-mode cycle compare with the change in fuel rate and emissions over other cycles?

For this item,two levels of emission control were defined, pre-1974 and 1974 and later model years. The average emissions and fuel consumption in grams/minute for the diesel trucks in each of the two groups was calculated for the 13-mode test, four steady-state conditions (idle, 24, 48, and 88 kph), three sinusoidal conditions (32, 48, and 64 kph), and two driving cycles (16 and 32 kph). Note that only 11 of the 12 diesel trucks were used in this item since one truck was a 1975 California diesel. Using the pre-1974 values as the base, the percent change from pre-1974 to 1974 and later model years was calculated for each of the test cycles. The results are shown in Table 53.

The average 13-mode emissions and fuel consumption decreased from pre-1974 to 1974 and later. The steady-state, sinusoidal and transient driving cycles all showed decreases in HC and NO_x emissions from pre-1974 to 1974 and later models. However, for CO and fuel consumption, some cycles showed an increase in average level from pre-1974 despite the fact that the average 13-mode levels decreased from pre-1974 to 1974 and later models. These results might be useful in estimating national average changes, if the 11 diesel trucks tested are assumed to be representative of the national diesel truck population. However, these results tell little about the relationship between changes in 13-mode emissions and changes in other test cycle emissions.

In an effort to help define this relationship, the percent change from the average pre-1974 value was calculated on each truck individually for each emission type on each test cycle. For a given emission (or fuel consumption), this gave a value of percent change for each truck. For each emission, a regression analysis was then performed with the percent change in each of the test cycles (other than the 13-mode) emissions as the dependent variable and the percent change in 13-mode emissions as the independent variable. Since there was only one truck which was manufactured to meet the 1975 California diesel standards, the regression analysis did not include that truck. The results of these regressions are shown in Table 54.

Of the three emissions and fuel consumption, only for NO_x and fuel consumption did the regressions show the majority of the relationships to be significant. For the transient driving cycles, the regressions were significant for both NO_x and fuel consumption. Since the relationship between the 13-mode test and actual driving cycles are of interest, the NO_x and fuel consumption relationships between 13-mode and the 16 and 32 kph driving cycles have been plotted as Figures 21 and 22. The regression lines are also shown on the figures.

Item 5 - How different are the rpm-time profiles and percent power-time profiles for a given transient cycle and load for different trucks?

TABLE 53. AVERAGE PERCENT CHANGE IN DIESEL EMISSIONS AND FUEL CONSUMPTION BETWEEN PRE-1974 and 1974 AND LATER DIESEL TRUCKS

	Percent Change in Average Values from Pre-1974 to 1974 and later			
Cycle	HC	CO	NO_x	Fuel Consumption
13-Mode	- 9.94	-30.06	-21.03	- 4.05
Steady State				
Idle	-20.00	-49.88	- 9.73	-11.90
24 kph	-24.25	+ 4.29	-39.29	+ 0.25
48 kph	-16.43	+ 5.73	-39.66	- 3.74
88 kph	-16.72	-65.87	-26.58	- 6.47
Sinusoidal				
32 kph	-22.53	-38.82	-25.73	- 3.44
48 kph	-21.70	-33.18	-26.47	- 1.08
64 kph	-15.40	-20.96	-39.66	+ 0.59
Transient				
16 kph	-17.60	-39.55	-21.14	- 3.29
32 kph	-17.52	-39.23	-19.35	- 4.62

Sample Size: 6 pre-1974 diesel trucks
5 1974 and later diesel trucks

TABLE 54. RELATIONSHIP OF CHANGE IN 13-MODE COMPOSITE RESULTS TO CHANGE IN DRIVING CYCLE RESULTS FOR 1974 AND LATER DIESEL TRUCKS (AVERAGE PRE-1974 BASE LEVEL)

Cycle	Average Speed, kph	(a) Intercept	(b) Slope ± Standard Error	r^2	Std. Dev.	Sig. Level
			HC			
Steady-State	0	-15.13	0.49 ± 0.51	0.238	33.4	
	24	-16.61	0.77 ± 0.24	0.781	15.4	*
	48	- 8.78	0.77 ± 0.22	0.797	14.8	*
	88	-14.47	0.23 ± 0.35	0.125	22.8	
Sinusoidal	32	-23.03	-0.05 ± 0.74	0.002	48.8	
	48	-19.43	0.23 ± 0.48	0.069	31.7	
	64	- 9.65	0.58 ± 0.34	0.492	22.3	
Transient	16	-16.52	0.11 ± 0.56	0.012	37.1	
	32	-17.89	-0.04 ± 0.45	0.002	29.8	
			CO			
Steady-State	0	-[illegible].73	0.14 ± 0.58	0.019	26.5	
	24	- 7.01	-0.38 ± 1.65	0.017	75.2	
	48	-15.77	-0.72 ± 1.74	0.053	79.4	
	88	-64.34	0.05 ± 0.42	0.005	19.0	
Sinusoidal	32	-47.82	-0.30 ± 0.97	0.031	44.1	
	48	-29.45	0.12 ± 0.90	0.006	40.9	
	64	-42.22	-0.71 ± 1.21	0.102	55.3	
Transient	16	8.54	1.03 ± 0.56	0.531	25.5	
	32	8.15	1.58 ± 0.60	0.700	27.2	
			NO_x			
Steady-State	0	11.58	1.01 ± 0.76	0.373	48.5	
	24	-25.92	0.64 ± 0.39	0.474	24.7	
	48	-29.79	0.47 ± 0.22	0.595	14.3	
	88	-11.91	0.70 ± 0.21	0.788	13.3	*
Sinusoidal	32	- 7.02	0.89 ± 0.35	0.679	22.6	
	48	- 6.69	0.94 ± 0.29	0.778	18.5	*
	64	-29.21	0.50 ± 0.12	0.848	7.8	*
Transient	16	2.28	1.11 ± 0.33	0.795	20.9	*
	32	2.86	1.06 ± 0.24	0.865	15.4	*
			Fuel Rate			
Steady-State	0	-7.43	1.10 ± 0.41	0.713	18.6	
	24	6.63	1.58 ± 0.75	0.595	34.4	
	48	1.41	1.27 ± 0.39	0.782	17.8	
	88	-3.15	0.82 ± 0.17	0.885	7.8	*
Sinusoidal	32	1.66	1.26 ± 0.35	0.815	16.0	
	48	4.61	1.41 ± 0.43	0.783	19.6	*
	64	5.04	1.10 ± 0.20	0.910	9.2	*
Transient	16	3.08	1.57 ± 0.32	0.892	14.5	*
	32	0.69	1.31 ± 0.34	0.831	15.7	*

Form of Equation: Y = a & bx
where: Y = percent change in driving cycle HC
X = percent change in 13-Mode HC

Significance level: * = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

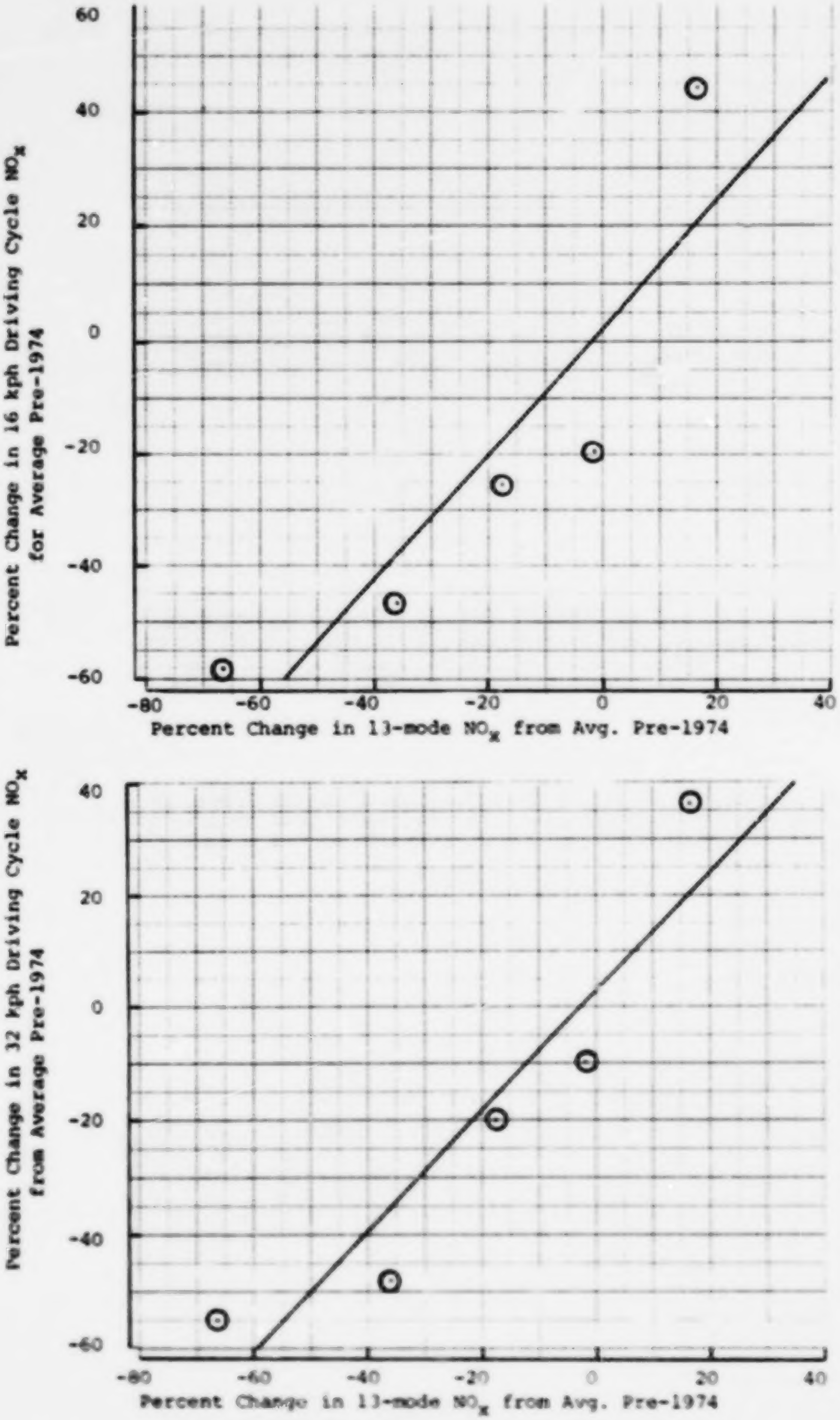
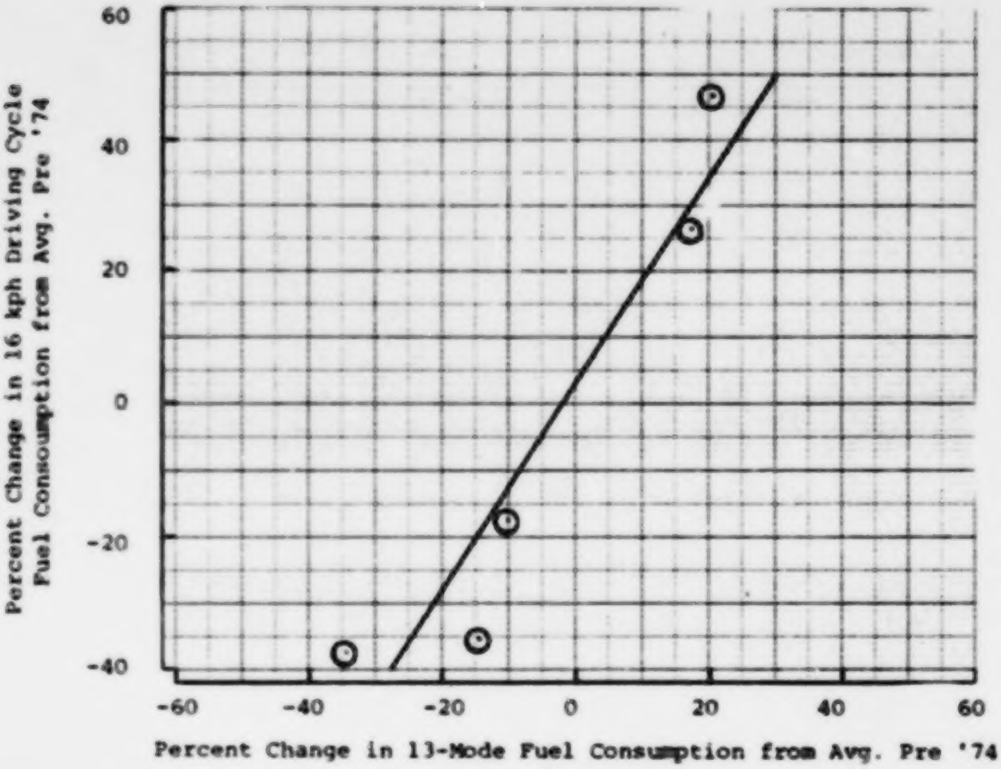


FIGURE 21. COMPARISON OF PERCENT CHANGE IN DRIVING CYCLE NO$_x$ EMISSIONS WITH PERCENT CHANGE IN 13-MODE NO$_x$ EMISSIONS



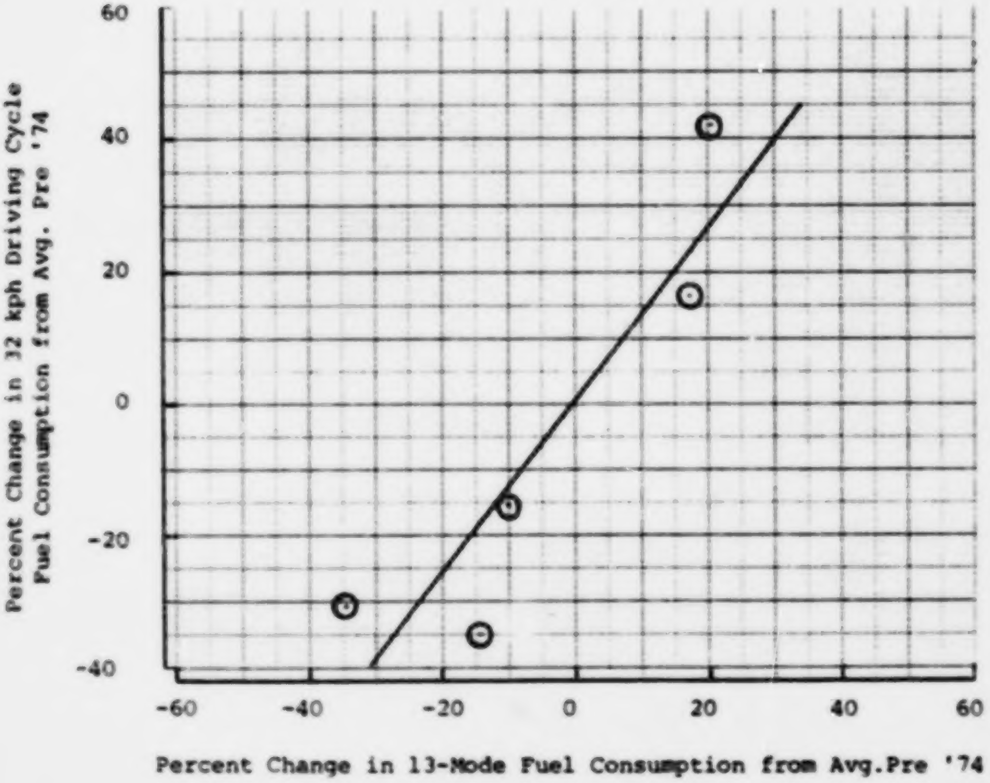


FIGURE 22. COMPARISON OF PERCENT CHANGE IN DRIVING CYCLE FUEL CONSUMPTION WITH 13-MODE PERCENT CHANGE

It was decided that the best way to approach this problem was to obtain rpm-percent power matrices for the 12 diesel trucks tested, similar to those produced under the CAPE-21 project. A special computer program was written to process the data tapes generated under Contract 68-03-2147 to obtain the desired matrices. The matrices for the 16 and 32 kph driving cycles for all 12 trucks are included in Appendix C as Tables C-15 through C-44. For the 16 kph transient cycle and the 32 kph transient cycle at half load on each truck, these matrices were condensed into time spent in various rpm intervals (regardless of power) and time spent in various percent power intervals (regardless of rpm). The cumulative percent times were then calculated for both the rpm and percent power for each truck. The cumulative distributions for each truck were then compared with the distribution of each of the other trucks, one at a time, using the Kolmogorov-Smirnov (KS)(22) test.

Table 55 lists truck pairs which showed no significant difference (at the 0.05 level) in cumulative distributions. As an aid to understanding this table, a description of the diesel trucks is included in Appendix A. There are 78 possible truck pairs, excluding the repeat cycles for Trucks 24 and 25. For the 32 kph transient cycle, 12 truck pairs had similar cumulative percent power distributions and four truck pairs had similar cumulative rpm distributions. The truck pairs that are similar are often not the ones that would be predicted from engine and body style. For instance, Trucks 23 and 24 are both tractors powered by Detroit Diesel 8V-71N engines and yet none of the cumulative distributions calculated were similar for the two trucks. Yet, Truck 19, which was a 2-axle van, had a percent power distribution similar to Trucks 26 and 27, both of which were tractors. Truck 26 was powered by a Detroit Diesel 6L-71N and Truck 27 was powered by a Cummins V8-903. The two trucks powered by Cummins NTC-290 engines, Trucks 21 and 25, had similar percent power and rpm distributions.

For the 16 kph transient cycle, 24 truck pairs had similar percent power distributions and eight truck pairs had similar rpm distributions. Here again, the similar truck pairs were not always the ones that might be expected. Only one truck pair (Trucks 21 and 25) showed agreement for both the power and rpm distributions on both the 32 and 16 kph cycles.

Since differences in rpm and percent power for trucks operating over the same driving cycle have important implications in the development of possible new certification cycles, it was decided to compare the matrices on a cell-by-cell basis. To do this, data were written in vector form (instead of matrix form) by extending each percent power row by the next lower one. For example, the data had the following form, y_{jk}, where "k" referred to rpm and was the fastest moving index and "j" referred to percent power and was the second fastest moving index.

The extended vector for each truck was compared with the vector of each other truck, one at a time, using the KS test statistic. This was done for both the 16 and 32 kph average speed driving cycles. Table 56 lists the trucks with similar vectors for the 32 and 16 kph transient driving cycles. Five pairs of trucks had similar percent time vectors on the 32 kph transient driving cycle. Ten pairs of trucks had similar percent time vectors on the 16 kph transient driving cycle. There were more diesel truck pairs than gasoline truck pairs with similar percent time distributions. However, it must be concluded that in the majority of cases, the diesel trucks did not have similar distributions.

TABLE 55. DIESEL TRUCK PAIRS SHOWING SIMILAR PERCENT POWER AND ENGINE RPM DISTRIBUTIONS USING THE KOLMOGOROV - SMIRNOV TEST

I. Truck pairs with similar distribution (at the 0.05 level) of time in various percent power intervals for the half load 32 kph transient driving cycle.

(19, 26)
(19, 27)
(21, 24)
(21, 25)
(21, 26)
(21, 29)

(23, 26)
(23, 27)
(24, 25)
(24, 25A)
(25, 25A)
(27, 29)

II. Truck pairs with similar distribution (at the 0.05 level) of time in various engine rpm intervals for the half load 32 kph transient driving cycle.

(20, 21)
(20, 24)

(21, 25)
(24, 25A)

III. Truck pairs with similar distribution (at the 0.05 level) of time in various percent power intervals for the half load 16 kph transient driving cycle.

(19, 20)
(19, 29)
(19, 30)
(20, 23)
(20, 27)
(20, 29)
(21, 22)

(21, 24)
(21, 25)
(21, 25A)
(21, 26)
(22, 24)
(22, 25A)
(22, 29)

(23, 26)
(23, 27)
(23, 29)
(24, 25)
(24, 25A)
(24, 26)
(24, 29)

(25A, 26)
(25A, 29)
(26, 29)

IV. Truck pairs with similar distribution (at the 0.05 level) of time in various engine rpm intervals for the half load 16 kph transient driving cycle.

(20, 21)
(20, 25)

(21, 25)
(21, 25A
(23, 26)

(24, 25)
(24, 27)
(27, 29)

TABLE 56. DIESEL TRUCK PAIRS WITH SIMILAR PERCENT TIME IN VARIOUS POWER AND RPM INTERVALS

I. Truck pairs with similar (at the 0. 5 level*) percent time in percent power and rpm intervals for 32 kph transient driving cycles.

(21, 24)
(21, 25)
(23, 26)
(24, 25)
(25, 25A) **

II. Truck pairs with similar (at the 0. 5 level*) percent time in percent power and rpm intervals for 16 kph transient driving cycles.

(20, 27)
(20, 29)
(21, 22)
(21, 24)
(21, 25)
(21, 25A) **
(22, 24)
(22, 29)
(23, 26)
(24, 25)

---

* defined by the Kolmogorov - Smirnov test statistics

** A is alternate test cycle

Item 6 - For an average speed of 32 kph, how well do sinusoidal fuel consumption and emissions approximate a fully-transient cycle fuel consumption and emissions? Above 32 kph, how well does a steady-state approximate a sinusoidal cycle?

The approach to this item was to perform a linear regression on all diesel trucks to determine if there was a relationship for fuel consumption and emissions between the 32 kph sinusoidal cycle and the 32 kph transient cycle; the 64 kph sinusoidal and the 64 kph steady-state. The 48 kph sinusoidal cycle was also compared to the 48 kph steady-state. A linear regression was performed on the half load results for each emission and fuel consumption. The regression coefficients and coefficient of determination for each regression is shown in Table 57. Scatter plots of the data are contained in Appendix C as Figures C-1 through C-12.

From the table, it can be seen that NO_x had the highest correlations for all three of the cycle pairs while CO had the lowest. For all types of emissions, the 64 kph sinusoidal and the 64 kph steady-state cycles were highly correlated. Except for fuel rate, there is a decreasing correlation for all variables of any two cycles as the cycles became less alike. The most obvious use for this data is to determine if sinusoidal excursions about a given speed could be used to predict emissions and fuel rate for fully transient cycles having the same average speed.

For CO emissions, the correlations are obviously not sufficient. For HC, NO_x, and fuel rate, the answer is a matter of judgment, depending on the accuracy required of the prediction.

It should also be pointed out that the correlation shown between the sinusoidal cycles and the transient cycles is for a specific transient cycle. The correlation between the sinusoidal and transient cycles for other transient cycles with different characteristics could be different.

Item 7 - Does load setting have the same effect on fuel rate and emissions for each average speed? Do fuel rate and emissions vary with average speed? Do fuel rate and emissions vary with different cycles at the same average speed?

These questions were included as one item since they can all be answered by performing a multiple regression analysis using load, speed, and speed times load as the variables for each emissions type and each test cycle type for each truck. This regression analysis was performed using data from each of the 12 trucks with separate regressions for each of the four emissions and each of the three cycle types, resulting in 144 equations. The coefficients for these equations are included in Appendix C as Tables C-45 through C-47 together with indications of "goodness of fit" of each equation. It should be pointed out that for these equations, load was kg/1000 and speed in kph/8. This was done to obtain variables of the same order of magnitude so that the load times speed term would not be unduly influenced by large differences in magnitude of the values. The form of the equation calculated is shown below:

$$\text{emission} = \text{constant} + b_1\,(\text{load}) + b_2\,(\text{speed}) + b_3\,(\text{load} \times \text{speed}).$$

TABLE 57. RESULTS OF REGRESSION ANALYSIS ON EMISSIONS AND TRUCK RATE FOR SEVERAL CHASSIS DYNAMOMETER TEST CYCLES

Dependent Variable	Independent Variable	Intercept	Slope ± Std. Dev.	r^2
HC Emissions				
32 kph Transient	32 kph Sinusoidal	0.368	0.519±0.111	0.686
48 kph Sinusoidal	48 kph Steady State	0.717	0.680±0.134	0.721
64 kph Sinusoidal	64 kph Steady State	-0.071	1.184±0.194	0.789
CO Emissions				
32 kph Transient	32 kph Sinusoidal	5.465	0.635±0.551	0.118
48 kph Sinusoidal	48 kph Steady State	2.048	0.791±0.438	0.246
64 kph Sinusoidal	64 kph Steady State	0.926	1.074±0.295	0.569
NO_x Emissions				
32 kph Transient	32 kph Sinusoidal	2.501	0.923±0.070	0.946
48 kph Sinusoidal	48 kph Steady State	-0.070	2.166±0.182	0.934
64 kph Sinusoidal	64 kph Steady State	0.665	1.791±0.099	0.971
Fuel Rate				
32 kph Transient	32 kph Sinusoidal	7.544	1.046±0.140	0.848
48 kph Sinusoidal	48 kph Steady State	-23.995	1.485±0.166	0.888
64 kph Sinusoidal	64 kph Steady State	108.008	0.979±0.137	0.837

To answer the first question, "Does load have the same effect on emissions for each average speed?", we can look at how load varies at a constant speed. Since speed is a constant, the equation reduces to:

$$\text{emission} = \text{new constant} + (b_1 + b_3 \times \text{speed})\ \text{load}$$

where new constant = constant + b_2 x speed.

If load had the same effect on emissions for each average speed, the load coefficient in the reduced equation (b_1 + b_2 x speed) would be the same for each speed. In other words, the emission change with load would be independent of speed. As can be seen from the reduced equation, as long as the coefficient for the load times speed term, b_3, is not zero, this will not be the case. Thus, it can be said that, in general, speed does alter the effect of load on emissions. The question is then, "Is this a significant effect?" More importantly, "Is load at a given speed even a significant variable?"

To answer these questions, the significance of each of the coefficients was examined using an F statistic. The significant coefficients are marked in Appendix Tables C-45 through C-47. Examining the tables, load at a given speed, coefficient b_1 appears to be a significant variable for HC on 17 percent of the trucks for the sinusoidal tests and for none of the trucks on the transient driving and steady-state cycles. The load times speed coefficient, b_2, was not significant for any of the trucks on the sinusoidal cycle or steady-state cycles. Eight percent (one truck) of the trucks in both the sinusoidal cycle and the driving cycle had HC emissions that were significantly affected both by load and by load times speed. Thus, it appears the HC emissions were not significantly influenced by load setting at a given speed and only on one truck from both the sinusoidal and driving cycles did speed significantly alter the effect of load on HC emissions.

The same type of analysis can be done for CO, NO_x, and fuel consumption. In general, load at a given speed was not significant for CO, NO_x, or fuel. It should be noted that this does not mean that these emissions and fuel consumption are not, at least partially, functions of load; it means either that load alone does not account for all of the change seen at constant speed or that the data are unable to show it. However, load times speed is significant for a large portion of the trucks for CO, NO_x, and fuel on all test cycles except the sinusoidal tests.

To summarize, load setting is generally not statistically significant in its influence on emissions and fuel consumption at a given speed. For HC, load setting does have a different effect on emissions for different speeds, but only occasionally does the relationship of HC emissions with load change significantly with speed. For CO, NO_x, and fuel consumption, while load at constant speed is generally not significant, the load times speed term generally is significant (except for the sinusoidal test cycles). This indicates that for CO, NO_x, and fuel consumption, load does not have the same effect on emissions for each average speed.

The next question was: Do fuel rate and emissions vary with average speed? To answer this question, load is held constant and the general equation reduced to:

$$\text{emissions} = \text{new constant} + (b_2 + (b_3 \times \text{load}))\ \text{speed}$$

where new constant = constant + b_1 (load).

If the reduced coefficient, $B_2 + (B_3 \times \text{load})$, is significantly different from zero for the test cycle and emissions (or fuel consumption) under consideration, then there is a variation with speed.

The different test cycles were examined individually beginning with the transient driving cycle. For HC, speed at a given load, coefficient b_2 is a significant variable for 50 percent of the trucks and load times speed coefficient b_3 is significant for 8 percent (one truck) of the trucks. For CO, speed at a given load is not significant for any of the trucks; but load times speed is significant for 58 percent of the trucks. For NO_x, speed at a given load is significant for 33 percent of the trucks and load times speed is significant for 75 percent of the trucks. For fuel consumption, speed at a given load is significant for 83 percent of the trucks and load times speed for 83 percent of the trucks.

The sinusoidal test cycles showed few trucks where speed at a given load is a significant variable for any of the variables except NO_x. For HC, speed was not a significant variable for any of the trucks and load times speed for 8 percent (one truck) of the trucks. For CO, speed was significant for 8 percent (one truck) of the trucks and load times speed was significant for 17 percent of the trucks. For NO_x, speed was significant for 42 percent of the trucks and load times speed for 17 percent of the trucks. For fuel consumption, speed was significant for 8 percent (one truck) of the trucks and load times speed for none of the trucks.

The steady-state test cycles showed speed at a given load as a significant variable more often than the sinusoidal test cycles. For HC, speed was a significant variable for 25 percent of the trucks and load times speed for none of the trucks. For CO, speed was not significant for any of the trucks, but load times speed for 67 percent of the trucks. For NO_x, speed was significant for 17 percent of the trucks and load times speed for 50 percent of the trucks. For fuel consumption, speed was significant for 75 percent of the trucks and load times speed for 74 percent of the trucks.

To summarize, fuel rate and emissions do vary with average speed. However, whether speed at a given load had a statistically significant influence on fuel consumption and emissions was dependent on the type of test cycle and emission type. Speed at a given load had a statistically significant influence on HC emissions on 0 to 50 percent of the trucks. In general, speed at a given load did not have a statistically significant influence on CO emissions. The exception was one truck on the sinusoidal cycles. Speed at a given load had a statistically significant influence on NO_x for 33 to 75 percent of the trucks; on fuel consumption for 8 to 83 percent of the trucks.

The last question of this item is: Do fuel rate and emissions vary with different cycles at the same average speed? For emissions and fuel consumption to be the same at a given speed and load for each of three cycles, the coefficients of the equations for that emission would have to be the same for each cycle. An examination of Appendix Tables C-45 through C-47 indicates that this is generally not the case. However, it is felt that a more direct way to answer this question is to directly compare the emissions and fuel rate for the same average speed and load conditions on each truck. These comparisons are shown in Tables 58 through 61 for HC, CO, NO_x, and fuel consumption, respectively. Since the test-to-test variability for these cycles has not been defined, it is difficult to determine at what level the cycle-to-cycle differences at the same speed are significant. However, some insight may be gained by examining the average values of all trucks for each cycle at a given speed. For HC emissions, there appears to be little difference between the 8 kph steady-state and 8 kph transient. For the higher speeds, the average steady-state HC emissions are appreciably higher than the average transient cycle HC emissions. There is apparently little, if any, difference between the average steady-state HC emissions and the average sinusoidal HC emissions at any of the tested speeds. It must be pointed out that individual truck emissions will vary from the pattern shown by the average emissions, so care must be taken in how the data is used.

The average CO emissions from the transient cycles are appreciably higher than the average CO emissions from the steady-state tests at all tested speeds. While the average CO emissions from the sinusoidal cycles are all higher than the average steady-state CO emissions, the values are close enough that further analysis is needed to determine if the differences are significant.

There is apparently little difference in the average NO_x emissions between the 8 kph steady-state and the 8 kph transient cycle. The other transient cycles (16, 24, and 32 kph) all have average NO_x values that are appreciably higher than the average NO_x values for the corresponding steady-state speed. The average NO_x emissions from the 32 kph sinusoidal cycle is appreciably higher than the 32 kph steady-state average NO_x emissions, while the 48 kph sinusoidal NO_x emissions are appreciably lower than the 48 kph steady-state NO_x emissions. The 64 kph sinusoidal and steady-state NO_x emissions are approximately equal. Except for the difference in fuel consumption between the 32 kph transient cycle and the 32 kph steady-state cycle, the fuel consumption at a given speed was within ± 10 percent of the average for each test cycle.

To summarize, for all of the emissions, some of the test cycles gave equivalent results at some of the tested speeds. The 64 kph steady-state and sinusoidal cycles always had equivalent average emissions (and fuel consumption). Again, it should be emphasized that individual truck emissions (and fuel consumption) varied from the relationships found in the average data and these average trends should not be used to define relationships for an individual vehicle.

Item 8 - How does the SARR data compare with other 32 kph transient driving cycles?

To answer this question, the average percent time frequency distributions of vehicle speed and engine rpm from the San Antonio Road Route (SARR) were compared with the same data from the 12 diesel trucks from Contract 68-03-2147. The time-in-percent power was not compared since percent power was not obtained on the SARR trucks. First, the percent time in various vehicle speeds for the three 32 kph driving cycles used

TABLE 58. COMPARISON OF DIESEL TRUCK HC EMISSIONS IN GRAMS/MIN
FROM DIFFERENT DRIVING CYCLES WITH THE SAME AVERAGE SPEED (HALF LOAD DATA)

Average Speed	Cycle	Truck Number 19	20	21	22	23	24	25	26	27	28	29	30	Avg.
08	SS	2.36	0.69	0.43	0.90	1.21	1.74	1.40	0.73	1.53	1.19	1.90	1.20	1.27
08	Trans	1.90	0.61	0.50	1.24	0.78	.98	1.36	0.48	1.20	1.08	1.00	0.67	.98
16	SS	3.16	0.73	0.62	3.47	1.36	1.96	2.23	0.87	3.39	1.83	2.33	1.31	1.94
16	Trans	2.50	0.76	0.63	1.40	1.06	1.32	1.79	0.63	1.43	1.31	1.14	0.84	1.23
24	SS	4.48	0.78	0.43	2.65	1.71	2.29	1.71	1.04	3.79	1.72	2.83	1.46	2.07
24	Trans	2.58	0.95	0.70	1.43	1.15	1.65	1.99	0.71	1.78	1.55	1.31	0.96	1.40
32	SS	4.55	0.69	0.50	3.88	1.59	1.86	1.99	1.04	3.35	1.85	2.76	1.50	2.13
32	Sine	3.65	1.16	1.21	2.68	1.16	1.91	3.27	0.87	2.93	1.83	1.57	1.07	1.94
32	Trans	2.83	0.76	0.60	1.33	1.29	1.72	1.70	0.83	1.68	1.61	1.08	1.09	1.38
48	SS	3.81	0.81	0.59	3.28	1.82	2.12	1.58	0.95	1.40	1.55	2.48	1.54	1.83
48	Sine	3.30	1.17	0.85	2.97	1.71	2.54	2.71	1.03	4.20	1.99	2.07	1.45	2.17
64	SS	4.40	0.72	0.65	2.70	1.83	2.18	1.69	1.15	1.88	1.32	2.49	1.96	1.91
64	Sine	5.51	0.67	0.55	2.50	1.91	2.82	1.61	1.24	2.30	1.57	2.52	1.92	2.09

TABLE 59. COMPARISON OF DIESEL TRUCK CO EMISSIONS IN GRAMS/MIN
FROM DIFFERENT DRIVING CYCLES WITH THE SAME AVERAGE SPEED (HALF LOAD DATA)

Average Speed	Cycle	Truck Number												Avg.
		19	20	21	22	23	24	25	26	27	28	29	30	
08	SS	2.6	1.1	2.0	1.5	4.8	4.3	2.3	1.0	1.9	3.7	3.4	0.9	2.5
08	Trans	2.0	1.4	3.6	6.9	3.4	4.5	3.7	1.9	3.6	3.5	1.9	0.8	3.1
16	SS	3.4	1.1	3.3	3.3	3.5	4.7	4.7	1.1	3.4	5.6	4.4	1.0	3.3
16	Trans	2.7	2.2	6.2	10.6	6.6	6.7	5.8	3.3	6.2	7.4	2.2	2.0	5.2
24	SS	3.4	1.5	2.3	2.4	2.8	5.1	4.0	1.3	3.4	4.8	5.3	0.9	3.1
24	Trans	3.1	3.4	7.9	12.6	9.1	9.0	8.3	4.1	9.0	11.6	2.7	3.1	7.0
32	SS	4.6	1.6	2.8	3.0	2.1	3.3	5.2	1.9	2.9	5.3	5.2	1.2	3.2
32	Sine	3.9	2.3	5.4	9.3	2.0	2.4	6.4	1.3	3.2	6.6	3.2	2.2	4.0
32	Trans	4.5	2.8	9.0	13.5	11.4	12.2	7.8	7.7	14.5	9.1	2.2	1.5	8.0
48	SS	4.2	1.6	3.5	2.4	1.8	3.6	5.9	1.2	1.7	4.9	4.7	0.9	3.0
48	Sine	3.0	1.8	5.7	9.0	2.8	4.7	6.7	1.5	6.6	7.2	3.8	2.4	4.6
64	SS	5.0	1.6	4.3	4.4	1.2	2.4	8.6	0.9	2.3	6.5	4.0	1.0	3.5
64	Sine	6.2	1.6	4.6	7.3	1.2	3.0	7.6	1.1	3.4	6.6	4.8	2.8	4.2

TABLE 60. COMPARISON OF DIESEL TRUCK NO_x EMISSIONS IN GRAMS/MIN
FROM DIFFERENT DRIVING CYCLES WITH THE SAME AVERAGE SPEED (HALF LOAD DATA)

Average Speed	Cycle	Truck Number 19	20	21	22	23	24	25	26	27	28	29	30	Avg.
08	SS	2.10	1.98	3.12	3.07	8.22	4.56	1.47	2.11	1.66	2.62	1.58	2.05	2.88
08	Trans	1.74	3.57	3.77	4.30	9.41	5.85	2.88	2.90	3.43	2.12	1.81	2.16	3.66
16	SS	2.45	2.43	6.01	5.76	10.57	5.70	3.41	2.97	3.19	3.59	2.19	2.37	4.22
16	Trans	2.48	5.90	7.12	7.12	16.01	10.13	5.63	5.22	5.71	3.57	2.93	3.72	6.30
24	SS	3.39	3.00	5.02	7.02	14.37	7.04	2.86	3.42	4.13	3.47	2.82	2.78	4.94
24	Trans	3.32	7.67	9.07	8.81	20.20	13.07	7.42	6.83	9.03	4.63	4.00	5.77	8.32
32	SS	3.51	3.44	5.78	6.98	17.05	6.68	3.92	4.03	4.74	4.02	3.37	3.41	5.58
32	Sine	4.12	8.61	10.60	8.55	28.09	14.35	7.15	7.33	8.62	4.37	4.87	6.13	9.40
32	Trans	4.75	10.93	12.86	12.42	27.06	16.72	11.05	9.82	11.57	4.99	5.53	6.38	11.17
48	SS	4.15	6.55	11.24	11.41	27.34	10.28	5.91	6.23	6.28	4.95	5.15	5.30	8.73
48	Sine	4.69	8.18	13.20	12.38	36.35	18.29	10.86	8.82	12.19	5.47	6.01	7.66	6.00
64	SS	7.18	11.65	17.08	22.71	47.66	15.86	11.71	11.27	12.67	7.25	7.98	9.95	15.25
64	Sine	7.36	11.40	18.98	24.83	49.13	17.98	12.83	11.53	15.35	6.98	8.52	10.80	16.31

TABLE 61. COMPARISON OF DIESEL TRUCK FUEL CONSUMPTION IN GRAMS/MIN FROM DIFFERENT DRIVING CYCLES WITH THE SAME AVERAGE SPEED (HALF LOAD DATA)

Average Speed	Cycle	Truck Number 19	20	21	22	23	24	25	26	27	28	29	30	Avg.
08	SS	69.23	120.16	124.83	42.01	119.23	205.03	91.36	86.44	92.09	109.10	69.50	90.09	101.59
08	Trans	64.68	109.22	109.59	91.61	104.64	130.09	110.01	73.20	104.65	83.19	59.59	60.88	91.78
16	SS	84.08	146.56	237.60	158.24	154.42	256.67	208.35	112.10	185.85	171.31	90.90	100.42	158.88
16	Trans	91.08	178.40	189.03	151.66	172.22	216.86	187.01	121.93	152.32	128.99	92.81	94.89	148.10
24	SS	124.57	183.33	188.96	138.39	202.15	310.99	168.30	139.34	220.51	153.33	115.86	124.25	172.50
24	Trans	118.01	228.21	236.94	190.73	218.90	287.92	240.09	162.52	215.64	157.47	125.59	130.91	192.74
32	SS	130.05	191.52	242.28	216.94	210.86	263.75	217.90	154.45	231.03	171.39	125.72	138.53	191.20
32	Sine	177.48	276.12	283.87	254.17	251.45	323.65	253.22	188.47	195.78	179.30	158.00	156.52	224.84
32	Trans	168.40	283.73	296.43	257.56	279.53	346.33	284.71	205.45	282.26	179.79	168.71	158.47	242.61
48	SS	139.38	299.12	351.31	254.55	296.49	360.52	261.80	194.82	227.16	183.46	166.21	181.65	243.04
48	Sine	162.35	273.82	301.74	267.12	317.99	403.83	302.52	204.00	318.52	192.13	186.16	189.30	259.96
64	SS	238.50	382.26	439.75	326.11	413.56	465.30	413.16	309.52	363.31	247.76	244.50	279.32	343.59
64	Sine	253.29	361.83	444.99	331.41	402.97	461.16	424.05	303.68	384.34	243.74	263.74	274.84	345.84

in Contract 68-03-2147 and the percent time in various vehicle speeds for the SARR were compared. This comparison is shown in Table 62. As an aid to visualizing the differences between the SARR and the dynamometer driving cycles, the cumulative percent of time for each of the cycles is shown in Figure 23.

As can be seen from the table and the figure, the dynamometer driving cycles are all fairly similar to each other (between 20 and 65 kph), however, they differ from one another at the high and low speed ends. The SARR differs from the dynamometer cycles in that it has less time at idle, more time between idle and 32 kph, and less time between 50 and 80 kph.

The comparison of the average engine rpm distribution for all diesel trucks driven on the three 32 kph dynamometer cycles and the average SARR engine rpm distribution is shown in Table 63. Unlike the comparison done on the gasoline-powered trucks, the CAPE-21 and ETABS diesel data were not available in a form that permitted comparison with the SARR data. The average cumulative percent time is shown in Figure 24 for the 12 diesel trucks and the SARR study.

From the table and the figure, it is evident that the rpm distribution of the two studies are somewhat different. The SARR trucks had less time at idle, more time between 1100 and 1700 rpm, and less time above 1700 rpm. However, the maximum difference between the two distributions is about 18 percentage points at 1700 rpm. A Kolmogorov-Smirnov test for statistical difference indicates that the two cumulative distributions are significantly different at the 0.05 level.

Item 9 - Can fuel rate and emissions be highly correlated with percent time at idle?

Data from the steady-state idle and the four transient driving cycles from all 12 trucks were used in this item. Table 64 lists the percent time at idle for each of the cycles. In order to obtain the best possible correlation for changes in emissions and fuel rate with time at idle, a technique developed by Daniel and Wood$^{(18)}$ was used. The technique involves using indicator (or dummy) variables to change the intercept and, if necessary, slope with individual truck. This technique was also used in the analysis of Item 10-2 for both the gasoline and diesel trucks. It is more fully explained under Item 10-2 in the gasoline truck analysis section (Section III).

All 12 diesel trucks were combined for each emission and tests were made to determine whether a linear model using a common slope or one with different slopes was most adequate. An F statistic was utilized and reflected the ratio of the error sum of squares for the model with different slopes to the error sum of squares for the increase from the common to the different slope model. In all cases, the F statistic was significant ($p < 0.05$) indicating individual fits of each truck were best. A logarithmic model did not yield any improvement except for fuel rate where a common slope model was obtained.

The regression coefficients for each emission type are given in Table 65 including the logarithmic fit for fuel rate. Examining Table 65, the

TABLE 62. PERCENT TIME AND CUMULATIVE PERCENT TIME SPENT IN VARIOUS SPEED INTERVALS FOR THE 32 kph DIESEL TRANSIENT CYCLES UNDER CONTRACT 68-03-2147 AND THE SAN ANTONIO ROAD ROUTE STUDIES

	Single Unit 2 axle (2D)		Single Unit 3 axle (3D)		Tractor Trailer (TT)		SARR	
Speed Interval kph	% Time	Cum. % Time	% Time	Cum. % Time	% Time	Cum. % Time	% Time	Cum. % Time
0.0 - 3.2	41.17	41.17	20.85	20.85	34.28	34.28	18.97	18.97
3.2 - 6.4	0.13	41.30	1.77	22.62	1.04	35.32	2.28	21.25
6.4 - 9.7	1.82	43.12	7.63	30.25	4.77	20.09	2.35	23.60
9.7 - 12.9	0.39	43.51	1.09	31.34	1.19	41.28	2.62	26.22
12.9 - 16.1	0.52	44.03	2.18	33.52	1.79	43.07	2.75	28.97
16.1 - 19.3	1.30	45.33	8.17	41.69	5.37	48.44	2.99	31.96
19.3 - 22.5	0.39	45.72	1.63	43.32	0.45	48.89	3.58	35.54
22.5 - 25.7	3.77	49.49	5.59	48.91	2.38	51.27	4.38	39.92
25.7 - 29.0	0.78	50.27	0.54	49.45	0.75	52.02	4.49	44.41
29.0 - 32.2	0.78	51.05	0.68	50.13	1.19	53.21	4.95	49.36
32.2 - 35.4	5.20	56.25	4.63	54.76	7.90	61.11	5.20	54.56
35.4 - 38.6	0.91	57.16	0.82	55.58	0.89	62.00	6.18	60.74
38.6 - 41.8	5.71	62.87	6.27	61.85	4.77	66.77	6.76	67.50
41.8 - 45.1	0.52	63.39	0.82	62.67	0.15	66.92	7.15	74.65
45.1 - 48.3	0.91	64.30	0.82	63.49	0.30	67.22	6.47	81.12
48.3 - 51.5	6.10	70.40	6.95	70.44	0.00	67.22	4.50	85.62
51.5 - 54.7	0.65	71.05	0.82	71.26	0.30	67.52	2.72	88.34
54.7 - 57.9	4.03	75.08	10.63	81.89	6.71	74.23	1.35	89.69
57.9 - 61.1	0.26	75.34	0.41	82.30	0.60	74.83	0.86	90.75
61.1 - 64.4	0.52	75.86	0.54	82.84	0.75	75.58	0.67	91.42
64.4 - 67.6	4.81	80.67	8.17	91.01	5.37	80.95	0.68	92.10
67.6 - 70.8	0.26	80.93	0.27	91.28	0.30	81.25	0.83	92.93
70.8 - 74.0	2.73	83.66	8.72	100.00	5.66	86.91	1.18	94.11
74.0 - 77.2	0.26	83.92	0.00		0.60	87.51	1.58	95.69
77.2 - 80.4	0.26	84.18	0.00		0.60	88.11	1.56	97.25
80.4 - 83.7	2.21	86.39	0.00		9.09	97.20	1.09	98.34
83.7 - 86.9	0.39	86.78	0.00		0.45	97.65	0.80	99.14
86.9 - 90.1	4.16	90.94	0.00		2.35	100.00	0.51	99.65
90.1 - 93.3	0.39	91.33	0.00		0.00		0.27	99.92
93.3 - 96.5	8.67	100.00	0.00		0.00		0.08	100.00
Avg. Speed, kph	33.16		31.83		31.31		31.29	

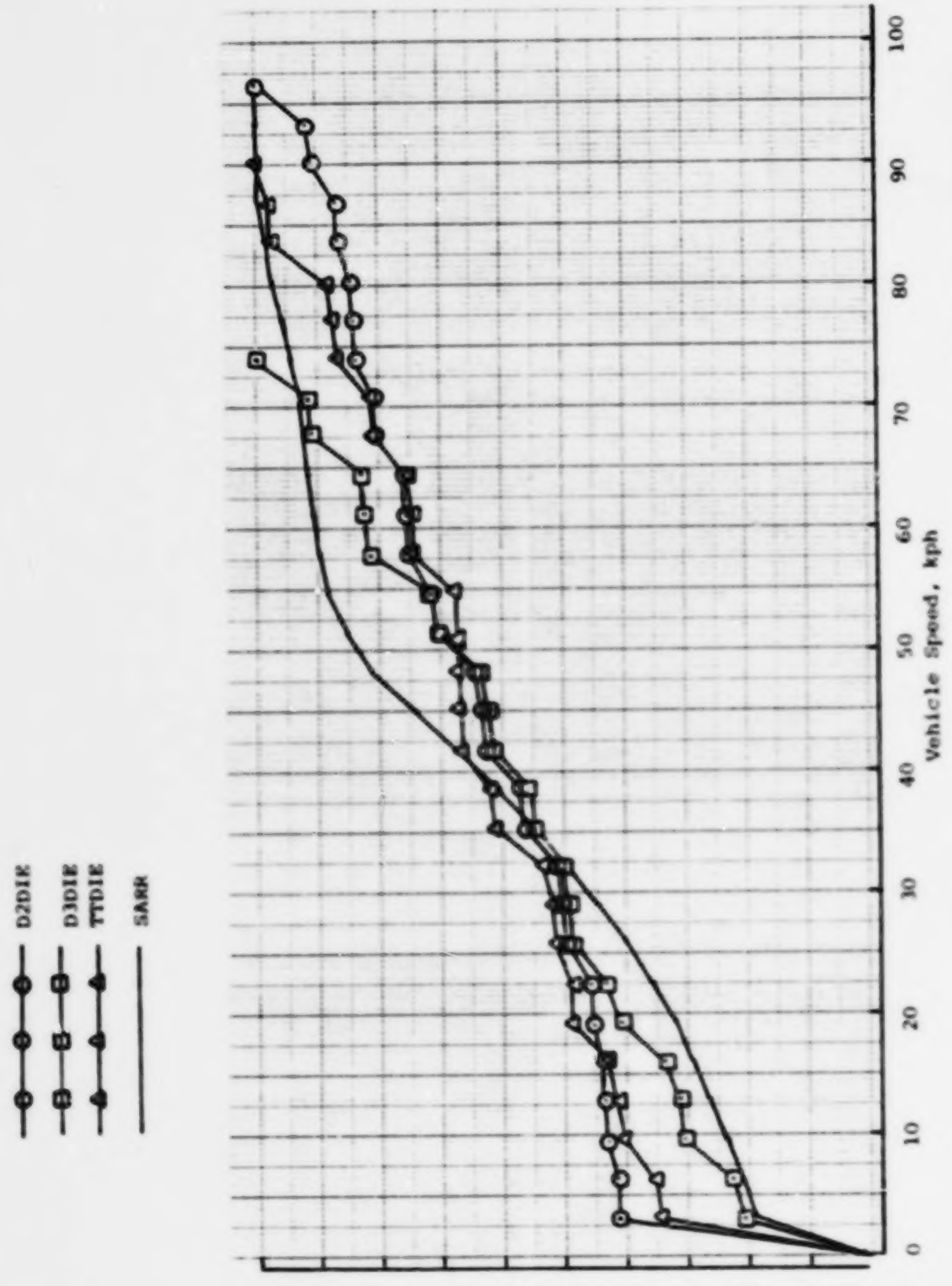


FIGURE 23. CUMULATIVE PERCENT TIME VERSUS VEHICLE SPEED FOR TWO DIESEL TRUCK STUDIES

TABLE 63. COMPARISON OF TIME SPENT IN VARIOUS RPM INTERVALS FOR TWO DIESEL TRUCK STUDIES

rpm[(a)]	12 Truck Dyno Study[(b)]		SARR[(c)]	
	% Time	Cum. % Time	% Time	Cum. % Time
200	0.06	0.06	0.00	0.00
400	6.38	6.44	2.81	2.81
600	24.35	30.79	9.45	12.26
800	2.43	33.22	11.64	23.90
1000	1.26	34.48	6.44	30.34
1200	2.09	36.56	7.74	38.08
1400	4.71	41.27	10.89	48.97
1600	8.79	50.06	12.41	61.38
1800	18.49	68.55	12.97	74.35
2000	15.56	84.11	12.20	86.55
2200	9.34	93.45	7.64	94.19
2400	3.70	97.15	3.98	98.17
2600	1.35	98.50	1.29	99.46
2800	1.05	99.55	0.40	99.86
3000	0.41	99.96	0.14	100.00
3200	0.04	100.00	0.00	

(a) rpm is midpoint of interval for 12 truck study and end of interval for SARR study

(b) 12 Truck Dyno Study - 32 kph half load driving cycles under contract 68-03-2147

(c) SARR - 10 diesel trucks tested on San Antonio Road Route under Contract 68-01-2113

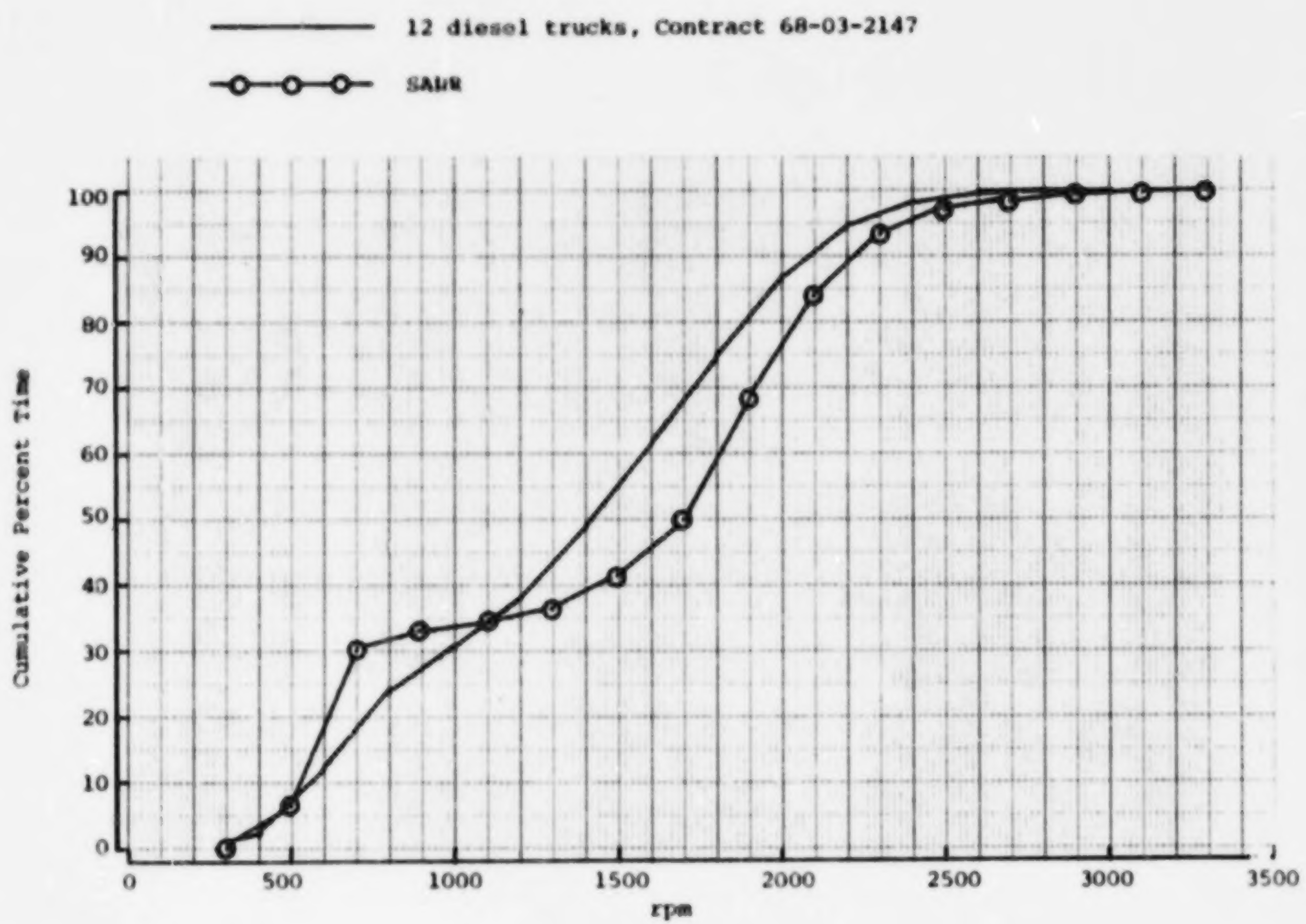


FIGURE 24. CUMULATIVE PERCENT TIME VERSUS ENGINE RPM FOR TWO DIESEL TRUCK STUDIES

TABLE 64. PERCENT TIME AT IDLE FOR VARIOUS DIESEL DYNAMOMETER TEST CYCLES

Cycle	Cycle No.	Speed	Truck Nos.	Percent Time At Idle
D2DIE	390741665	05	19, 29	58.7
	1527266763	10	↓	48.3
	1137788723	15		35.7
	555005187	20		40.4
D3DIE	882238513	05	28, 30	58.2
	202042971	10	↓	42.7
	743630625	15		33.2
	1200794289	20		16.8
TTDIE	767793819	05	20, 21, 22,	71.1
	802433547	10	23, 24, 25,	51.7
	605752003	15	26, 27	37.0
	462050771	20	↓	32.6

TABLE 65. REGRESSION RESULTS FOR EMISSIONS AND FUEL RATE AS A FUNCTION OF PERCENT TIME AT IDLE

Truck No.	Intercept	Slope ± Std. Dev.	r^2	Truck No.	Intercept	Slope ± Std. Dev.	r^2	Truck No.	Intercept	Slope ± Std. Dev.	r^2
		HC Emissions				CO Emissions				NO_x Emissions	
19	4.015	-0.034±0.004	0.964	19	5.136	-0.044±0.016	0.726	19	5.364	-0.048±0.019	0.684
20	1.173	-0.309±0.002	0.877	20	4.510	-0.043±0.006	0.942	20	13.709	-0.136±0.023	0.922
21	0.853	-0.005±0.001	0.876	21	12.494	-0.120±0.007	0.990	21	16.120	-0.160±0.028	0.916
22	1.637	-0.006±0.002	0.835	22	18.497	-0.157±0.006	0.996	22	15.254	-0.144±0.026	0.911
23	1.666	-0.012±0.001	0.989	23	14.559	-0.139±0.024	0.921	23	35.012	-0.344±0.045	0.950
24	2.300	-0.018±0.001	0.997	24	15.456	-0.150±0.023	0.936	24	21.514	-0.205±0.028	0.948
25	2.603	-0.019±0.004	0.882	25	11.650	-0.108±0.009	0.981	25	13.651	-0.139±0.027	0.896
26	1.100	-0.009±0.001	0.982	26	8.682	-0.089±0.026	0.792	26	11.950	-0.116±0.024	0.889
27	2.480	-0.020±0.003	0.954	27	17.104	-0.177±0.044	0.843	27	14.933	-0.152±0.025	0.925
28	1.962	-0.015±0.001	0.980	28	12.512	-0.199±0.036	0.784	28	5.785	-0.050±0.009	0.914
29	1.659	-0.012±0.002	0.950	29	3.563	-0.029±0.003	0.970	29	6.518	-0.062±0.022	0.725
30	1.265	-0.010±0.000	0.997	30	2.704	-0.023±0.014	0.464	30	7.290	-0.070±0.014	0.890
		Fuel Rate				ln (Fuel Rate)					
19	198.4	-1.873±0.633	0.745	19	6.007						
20	373.2	-3.458±0.371	0.968	20	6.619						
21	387.8	-3.668±0.417	0.963	21	6.680						
22	322.5	-3.040±0.481	0.930	22	6.514						
23	362.3	-3.440±0.416	0.958	23	6.598						
24	458.8	-4.354±0.453	0.969	24	6.840						
25	384.2	-3.659±0.303	0.980	25	6.639	-0.030±0.001	0.966				
26	266.6	-2.560±0.326	0.954	26	6.264						
27	356.0	-3.450±0.537	0.931	27	6.568						
28	209.8	-1.870±0.196	0.968	28	6.087						
29	202.9	-1.934±0.641	0.752	29	6.013						
30	178.0	-1.697±0.246	0.941	30	5.811						

Notes: 1. Form of equation, except ln (Fuel Rate) emissions = $b_0 + b_1$ (% time at idle)
2. Form of equation for ln (Fuel Rate) ln(fuel rate) = $b_0 + b_1$ (% time at idle)
3. Number of data points for each equation = 5

variation in slope for each truck are plainly evident for each of the emissions. The coefficient of variation (r^2) for the relationships generally indicates a good fit, especially for HC emissions.

The conclusion, then, is that fuel rate can be highly correlated with percent time at idle using a logarithmic equation with all trucks having a common slope but different intercepts. The exhaust emissions can, in general, be correlated to percent time at idle but only if a different equation is used for each truck.

It should be kept in mind that this regression analysis was done using percent time at idle from a particular set of driving cycles. Whether the relationship would be the same for other driving cycles with the same average speed is not known.

Item 10

Four items of analysis are required to assess the effects of speed, load, and power/load ratio on heavy-duty vehicles. The analyses need to be performed using available heavy-duty data bases. The data bases to be considered for the diesel trucks are (1) 10 diesel trucks tested over the SARR and (2) 12 diesel trucks tested over a transient 20 mph dynamometer driving schedule. For this item, the units of measure are expressed in mixed English-metric as requested since the results are to be used in that form in another EPA publication.

> Item 10-1 - For each of the two data bases, a regression should be performed for emissions as the dependent variable, weight/power ratio as the independent variable. The weight is the vehicle test weight and the power is CID. The regression should be linear unless a plot of the data indicate a better functional form. Within each data base, separate regressions should be performed for each of the following model year groupings: pre-1974 diesel, 1974-1975 diesel, and 1975 California diesel.
>
> All emission data should be expressed in grams/mile. Where multiple tests were performed on the same truck at different loads, these data points should be included and assumed independent. The average weight/power ratio should be computed for each of the data base/model year groups.

Table 66 contains the average weight/CID ratio for each of the truck groupings. Also available in the table are average test weight, average CID, and average mileage of each group.

Linear regression analyses were performed for each truck group with emissions or fuel consumption as the dependent variable and weight/CID ratio as the independent variable. The regression equation for each emission and fuel consumption of each truck group are contained in Table 67.

Examining the results of the regression analyses shown in Table 67, it appears that weight/CID has a significant effect on CO emissions for all truck groups. For fuel rate and NO_x emissions, weight/CID has a

TABLE 66. AVERAGES OF SOME IMPORTANT VARIABLES FROM TWO DIESEL TRUCK STUDIES

Group*	Average Wt., lbs	Average Wt/CID	Average Mileage	CID	No. of Trucks
1. SARR Pre-1974 Diesel	38,676	63.45	107,525	637.2	10
2. 1974-1975 Diesel	35,400	67.67	17,202	548.	15
3. Pre-1974 Diesel	39,778	55.76	185,167	719.00	18
4. 1975 California Diesel	49,000	57.31	1,856	855.00	3

---

* Data Source: Group 1 - EPA Contract 68-01-2113
Group 2 - EPA Contract 68-03-2147
to 4

TABLE 67. RESULTS OF REGRESSION ANALYSIS OF EMISSIONS AND FUEL RATE AS A FUNCTION OF WEIGHT/CID FOR VARIOUS DIESEL TRUCK GROUPS

Group	Constant	Wt/CID ± Std. Dev.	r^2	Std. Err.	No. of Data Points
		HC Emissions			
1. SARR Pre-1974 Diesel	7.231	-0.055 ± 0.036	0.225	2.140	10
2. 1974-1975 Diesel	3.919	-0.000 ± 0.009	0.000	1.174	15
3. Pre-1974 Diesel	6.297	-0.031 ± 0.012	0.279*	1.623	18
4. 1975 California Diesel	2.420	-0.001 ± 0.002	0.158	0.098	3
		CO Emissions			
1. SARR Pre-1974 Diesel	-28.591	0.821 ± 0.261	0.553*	15.366	10
2. 1974-1975 Diesel	-1.838	0.333 ± 0.108	0.424**	13.935	15
3. Pre-1974 Diesel	11.404	0.362 ± 0.098	0.462**	12.870	18
4. 1975 California Diesel	4.200	0.073 ± 0.000	1.000***	0.000	3
		NO_x Emissions			
1. SARR Pre-1974 Diesel	10.147	0.135 ± 0.111	0.158	6.516	10
2. 1974-1975 Diesel	9.092	0.311 ± 0.093	0.460**	12.086	15
3. Pre-1974 Diesel	4.726	0.570 ± 0.119	0.590***	15.696	18
4. 1975 California Diesel	10.930	0.345 ± 0.062	0.969	2.523	3
		Fuel Consumption			
1. SARR Pre-1974 Diesel	0.150	0.001 ± 0.001	0.082	0.047	10
2. 1974-1975 Diesel	0.132	0.001 ± 0.001	0.290*	0.072	15
3. Pre-1974 Diesel	0.141	0.002 ± 0.000	0.656***	0.037	18
4. 1975 California Diesel	0.160	0.002 ± 0.000	0.988	0.008	3

Notes:
1. Weight = truck wt/1000 = lb/1000
2. CID = cubic inch displacement
3. Fuel is in gallons/mile
4. Significance: * = 0.05
   ** = 0.01
   *** = 0.001
5. Group 1 - EPA Contract 68-01-2113
   Group 2 - EPA Contract 68-03-2147
   to 4

all truck groups. For fuel rate and NO_x emissions, weight/CID has a significant effect for half of the truck groups. Since displacement is, in general, proportional to some design point power, the weight/CID ratio could be thought of as a weight/rated power ratio. The slopes of the equations for CO, NO_x, and fuel are all positive, indicating that for a given size engine, as vehicle weight increases, fuel consumption, NO_x, and CO emissions also increase. This result is expected for fuel consumption. Since it takes more work to move a larger vehicle, the same size engine would naturally require more fuel. Emissions of NO_x are also known to increase with engine power, so the same reasoning could explain the NO_x behavior. The physical reasons behind the increase in CO emissions with increased weight/CID are not apparent. It is also interesting to note that all of the diesel HC emissions have negative slopes with weight/CID, while the HC emissions from gasoline-powered trucks (shown in Section III, Table 32) all have positive slopes.

The regression equations, in general, had small coefficients of determination (r^2), even on truck groups where the emissions and weight/CID relationship was indicated to be significant. In an effort to improve the coefficients of determination, an exponential curve fit was also performed since examination of the plots indicated that an exponential equation might better fit some of the data. While this regression analysis did improve some of the coefficients of determination slightly, it also decreased others. Overall, it was felt that there was little to be gained by using an exponential fit.

The small values of r^2 and large standard error values indicate a considerable amount of data scatter. This should not be too surprising since it has been shown in past studies that engine model (i.e., manufacturer, size, ancillary equipment and model year) was the most significant variable in explaining differences in emission levels from a large group of trucks. Thus, the data used in this analysis is in reality what statisticians term "nested" data; that is, within the data, there are individual slopes. Unfortunately, in this study, there are insufficient data to identify each of the groups.

One other caution should be mentioned before ending the discussion on this item. The data points used for each truck group are, in general, few in number. Also, the weight/CID range covered by the SARR trucks is small. To aid in comparison of the data base average emissions for each data base, average emissions for each data base are given in Table 68.

> Item 10-2 - For each of the model year groups within data base 2, plots should be made for emissions versus average speed. The speed cycles to be considered are 5, 10, 15, and 20 mph transient cycles; 30 and 40 mph sinusoidal cycles; and 55 mph steady-state cycle. The half load data points should suggest an appropriate regression form (log (emissions) provided the best fit for light-duty with a linear and quadratic term for speed). Speed should be expressed in mph and emissions in grams/mile, and fuel consumption in gallons/mile.

TABLE 68. AVERAGE EMISSIONS AND FUEL CONSUMPTION
FOR TWO DIESEL TRUCK STUDIES

Group*	Emissions, grams/mi HC	CO	NO_x	Fuel gal/mi	No. of Trucks
1. SARR Pre-1974 Diesel	3.71	23.5	18.74	0.19	10
2. 1974-1975 Diesel	3.90	20.72	30.13	0.22	15
3. Pre-1974 Diesel	4.59	31.58	36.53	0.22	18
4. 1975 California Diesel	2.36	8.40	30.73	0.26	3

---

* Data Source: Group 1 - EPA Contract 68-01-2113
Group 2 - EPA Contract 68-03-2147

** For Groups 3 and 4, emissions are averages of all trucks in the group at empty, half, and full weight for the 20 mph transient driving cycle

These regression equations will be normalized to either the average speed of the SARR or the average speed of the CAPE-21 data. The normalization will be performed by EPA.

All trucks of a given model year group will be combined for the regressions unless examination of individual truck plots indicates that a better approach would be to regress each truck separately and average those results.

As mentioned in the discussion of Item 10-1, engine model has been shown to be a significant variable in studies of truck emissions. The trucks within data base 2, the 12 diesel-powered trucks tested at the seven different average speed conditions, provide an excellent example of "nested" data.

In order to obtain the best possible prediction model for changes in emissions with speed, a technique involving using indicator (or dummy) variables to change the intercept and, if necessary, slope with individual truck was employed.(18) The equations used are described in Section III of this report under the analysis of Item 10-2 for the gasoline-powered trucks.

First, the data was processed to obtain an equation for each truck, each equation with a different intercept but a common slope. Next, the data was processed to determine if it could be represented better by straight lines with individual slopes. The hypothesis that the slope coefficients do not improve the fit was tested by the F ratio of the residual mean square due to adding extra slope variables to the common slope equation, divided by the residual mean square of the individual slope equation.(18) If the F ratio was not significant at the 0.05 significance level, the common slope equation was deemed adequate.

The regression coefficients for this study are given in Tables 69 through 72. Where a common slope could be used, the individual slopes are not given. The plots of the equations are not included in this report, but were previously mailed to EPA, ECTD, Ann Arbor, Michigan. It was suggested by EPA that perhaps a logarithmic equation might fit the data since this equation form provided the best fit for light-duty emissions as a function of speed. Therefore, the procedure detailed above was repeated twice. The first equation used was:

$$\ln\ (\text{emissions}) = b_0 + b_1\ (\text{speed}).$$

The second repetition used the equation:

$$\ln\ (\text{emissions}) = b_0 + b_1\ (\text{speed}) + b_2\ (\text{speed}^2).$$

In general, these equation forms have slightly better coefficients of determination. More importantly, these equation forms permitted the use of a common speed coefficient for each truck group for a given emission. Since the equation forms with the speed squared term gave the best coefficients of determination, it is felt that this equation form should be used to describe the effect of speed on emissions for HC, CO, and NO_x. The

TABLE 69. RESULTS OF REGRESSION ANALYSIS FOR HC EMISSIONS AS A FUNCTION OF VEHICLE SPEED FOR VARIOUS DIESEL TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Speed Coefficient	r^2	Std. Error	n
Pre-1974 Diesel	19	14.340	-0.156±0.020	0.762***	2.148	42
	21	6.382				
	22	10.226				
	23	8.554				
	27	10.607				
	28	9.605				
1974-75 Diesel	24	9.893	-0.145±0.037	0.804***	1.611	35
	25	12.658	-0.236			
	26	4.183	-0.052			
	29	8.315	-0.126			
	30	6.102	-0.083			
1975 Calif. Diesel	20	5.482	-0.098±0.024	0.773**	1.036	7

Note: 1. Equation form: $Y = b_0 + b_1$ (speed)
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 70. RESULTS OF REGRESSION ANALYSIS FOR CO EMISSIONS AS A FUNCTION OF VEHICLE SPEED FOR VARIOUS DIESEL TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Speed Coefficient	r^2	Std. Error	n
Pre-1974 Diesel	19	29.589	-0.722±0.099	0.700***	10.585	42
	21	42.875				
	22	59.126				
	23	41.312				
	27	44.185				
	28	47.932				
1974-75 Diesel	24	53.524	-1.077±0.122	0.886***	5.331	35
	25	39.505	-0.647			
	26	23.120	-0.414			
	29	16.636	-0.271			
	30	11.493	-0.161			
1975 Calif. Diesel	20	15.299	-0.278±0.058	0.822 **	2.525	7

Note: 1. Equation form: $Y = b_0 + b_1$ (speed)
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 71. RESULTS OF REGRESSION ANALYSIS FOR NO_x EMISSIONS AS A FUNCTION OF VEHICLE SPEED FOR VARIOUS DIESEL TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Speed Coefficient	r^2	Std. Error	n
Pre-1974 Diesel	19	16.647	-0.137±0.068	0.930***	7.307	42
	21	41.334				
	22	42.425				
	23	90.305				
	27	35.084				
	28	20.049				
1974-75 Diesel	24	66.412	-0.731±0.247	0.678***	10.785	35
	25	30.227	-0.041			
	26	26.898	0.027			
	29	18.160	-0.106			
	30	8.546	0.808			
1975 Calif. Diesel	20	31.949	-0.081±0.241	0.022	10.492	7

Note: 1. Equation form: $Y = b_0 + b_1$ (speed)
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 72. RESULTS OF REGRESSION ANALYSIS FOR FUEL CONSUMPTION AS A FUNCTION OF VEHICLE SPEED FOR VARIOUS DIESEL TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Intercept	Speed Coefficient	r^2	Std. Error	n
Pre-1974 Diesel	19	0.351	-0.008±0.019	0.132	1.992	42
	21	0.488				
	22	0.448				
	23	2.293				
	27	0.455				
	28	0.391				
1974-75 Diesel	24	0.456	-0.005±0.001	0.885***	0.036	35
	25	0.357	-0.004			
	26	0.206	-0.001			
	29	0.185	-0.001			
	30	0.192	-0.001			
1975 Calif. Diesel	20	0.334	-0.003±0.001	0.542	0.054	7

Note: 1. Equation form: $Y = b_0 + b_1$ (speed)
2. Speed in miles per hour
3. Fuel Consumption in gallons/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

equation coefficients for each of the emissions by truck group are given in Tables 73 through 76.

To aid in normalizing this data base to some given speed, the average emissions for the 20 mph transient driving cycle are given in Table 77 for each truck group. While only the half load data was used in the above analysis, the average emissions at empty and full load are shown for comparison.

> Item 10-3 - For the 1974-1975 diesel trucks in data base 2, a regression should be performed with emissions (20 mph cycle) as the dependent variable and mileage as the independent variable. Weight/power ratio should be included as a covariate (this assumes that for all sized trucks, the same deterioration rate holds). The same type of regression analysis should be performed for all trucks in data base 1. SARR emission values should be used in these regressions.

The required regression analysis on these data bases was performed. The results are shown in Table 78. Three of eight truck groups had regressions that were considered significant. These three consisted of both of the CO regressions and NO_x for the 1974-1975 group. Even for those regressions considered significant, the r^2 value indicates a good deal of data scatter. Considering that these were all in-service trucks with a wide variation in maintenance quality, the data scatter is probably not surprising. Of more interest is the variation in value of the mileage coefficient of the two truck groups for a given emission specie and the negative coefficients for HC and fuel consumption. Also of interest is the positive mileage coefficients for NOx. This means that NO_x emissions increase as mileage increases. The reasons for the behavior of these emissions is not immediately apparent. All things considered, it is not recommended that these equations be used to define the behavior of diesel truck emissions with mileage without further study.

> Item 10-4 - For each of the model year groups within each of the two data bases, a regression should be performed with emissions as the dependent variable and test weight as the independent variable. Test weight/power ratio should be included as a covariate. The emissions will be the SARR emissions for data base 1 and the 20 mph cycle for data base 2.
>
> The average test weight should be computed for vehicles in data base 1. The average test weight for the empty, half, and full load tests should be computed for each of the model year groups in data base 2 as well as for all diesel trucks in data base 2.
>
> These regressions will later be normalized by EPA to the average test weight and average weight/power ratio built into the tabled emission values. These regressions will be able to predict the effects of changes in load (where load is the difference in average test weight).

TABLE 73. RESULTS OF REGRESSION ANALYSIS FOR EMISSIONS AS A LOGARITHMIC FUNCTION OF SPEED FOR VARIOUS DIESEL TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Int.	Spd. Coefficient	Spd. ^{2} Coefficient	r^2	Std. Error	n
Pre-1974 Diesel	19	3.275	-0.055±0.010	0.0004±0.0002	0.907***	0.249	42
	21	1.671					
	22	2.658					
	23	2.461					
	27	2.785					
	28	2.593					
1974-75 Diesel	24	2.679	-0.051±0.011	0.0005±0.0002	0.846***	0.250	35
	25	2.594					
	26	1.930					
	29	2.459					
	30	2.253					
1975 Calif. Diesel	20	2.1928	-0.072±0.208	0.0006±0.0003	0.939***	0.707	7

Note: 1. Equation form: $\ln(Y) = b_0 + b_1\,(\text{speed}) + b_2\,(\text{speed}^2)$
2. Speed in miles per hour
3. Emissions in grams/miles
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 74. RESULTS OF REGRESSION ANALYSIS FOR CO EMISSIONS AS A LOGARITHMIC FUNCTION OF SPEED FOR VARIOUS DIESEL TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Int.	Sped. Coefficient	Spd. ^{2} Coefficient	r^2	Std. Error	n
Pre-1974 Diesel	19	3.766	-0.092±0.019	0.0010±0.0003	0.743***	0.475	42
	21	4.490					
	22	4.939					
	23	4.089					
	27	4.486					
	28	4.707					
1974-75 Diesel	24	4.132	-0.072±0.020	0.0006±0.0003	0.780***	0.467	35
	25	4.317					
	26	3.471					
	29	3.445					
	30	3.197					
1975 Calif. Diesel	20	3.3753	-0.088±0.028	0.0008±0.0005	0.912**	0.791	7

Note: 1. Equation form: $\ln(Y) = b_0 + b_1 (\text{speed}) + b_2 (\text{speed}^2)$
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 75. RESULTS OF REGRESSION ANALYSIS FOR NO_x EMISSIONS AS A LOGARITHMIC FUNCTION OF SPEED FOR VARIOUS DIESEL TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Int.	Spd. Coefficient	Spd.^{2} Coefficient	r^2	Std. Error	n
Pre-1974 Diesel	19	3.069	-0.043±0.005	0.0006±0.0001	0.970***	0.125	42
	21	4.121					
	22	4.149					
	23	4.959					
	27	3.942					
	28	3.272					
1974-75 Diesel	24	4.393	-0.054±0.012	0.0009±0.0002	0.733***	0.276	35
	25	3.916					
	26	3.841					
	29	3.292					
	30	3.751					
1975 Calif. Diesel	20	4.1480	-0.074±0.025	0.0012±0.0004	0.692	0.373	7

Note: 1. Equation form: $\ln(Y) = b_0 + b_1 (\text{speed}) + b_2 (\text{speed}^2)$
2. Speed in miles per hour
3. Emissions in grams/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 76. RESULTS OF REGRESSION ANALYSIS FOR FUEL CONSUMPTION AS A LOGARITHMIC FUNCTION OF SPEED FOR VARIOUS DIESEL TRUCK GROUPS FROM CONTRACT 68-03-2147

Group	Truck No.	Inter.	Spd. Coefficient	Spd.^{2} Coefficient	r^2	Std. Error.	n
Pre-1974 Diesel	19	-1.465	-0.029±0.025	0.0003±0.0004	0.363*	0.635	[illegible]
	21	-0.801					
	22	-0.958					
	23	-0.305					
	27	-0.921					
	28	-1.253					
1974-75 Diesel	24	-0.568	-0.043±0.0004	0.0005±0.0001	0.949**	0.095	35
	25	-0.766					
	26	-1.181					
	29	-1.325					
	30	-1.273					
1975 Calif. Diesel	20	-0.6721	-0.545±0.112	0.0007±0.0002	0.896*	0.292	7

Note: 1. Equation form: $\ln (Y) = b_0 + b_1 (\text{speed}) + b_2 (\text{speed}^2)$
2. Speed in miles per hour
3. Fuel Consumption in gallons/mile
4. Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE 77. AVERAGE EMISSIONS FROM THE 20 mph TRANSIENT CYCLE
FOR TRUCKS TESTED UNDER CONTRACT 68-03-2147

	Empty Load, g/min				Half Load, g/min				Full Load, g/min			
	HC	CO	NO_x	FC	HC	CO	NO_x	FC	HC	CO	NO_x	FC
1974-1975 Diesel	4.05	12.9	21.71		3.89	19.1	30.06		3.93	31.5	40.23	
Pre-1974 Diesel	4.92	18.8	29.20		4.73	31.4	37.67		4.31	46.2	45.47	
1975 California Diesel	2.41	6.3	19.65		2.25	8.4	32.71		2.45	10.8	40.85	

TABLE 78. RESULTS OF REGRESSION ANALYSIS FOR EMISSIONS AND FUEL RATE AS A FUNCTION OF MILEAGE AND WEIGHT/CID FOR TWO DIESEL TRUCK GROUPS

Group	Constant	Mileage/10000	Wt/CID	r^2	Std. Err.	No. of Trucks
			HC Emissions			
1. SARR Pre-1974 Diesel	6.191	0.082 ± 0.659	-0.053 ± 0.034	0.391	2.028	10
2. 1974-1975 Diesel	4.234	-0.267 ± 0.227	0.002 ± 0.009	0.104	1.157	15
			CO Emissions			
1. SARR Pre-1974 Diesel	-33.275	0.369 ± 0.460	0.833 ± 0.267	0.591*	15.719	10
2. 1974-1975 Diesel	-4.447	2.210 ± 2.767	0.316 ± 0.111	0.453*	14.133	15
			NO_x Emissions			
1. SARR Pre-1974 Diesel	8.867	0.101 ± 0.200	0.138 ± 0.116	0.187	6.842	10
2. 1974-1975 Diesel	8.195	0.760 ± 2.453	0.305 ± 0.099	0.464*	12.529	15
			Fuel Consumption			
1. SARR Pre-1974 Diesel	0.155	-0.000 ± 0.001	0.001 ± 0.001	0.091	0.050	10
2. 1974-1975 Diesel	0.133	-0.001 ± 0.015	0.001 ± 0.001	0.289	0.075	15

Notes:
1. Equation form: $y = b_0 + b_1$ (miles/1000) + b_2 ratio
2. Ratio = (weight/1000)/CID = (lb/1000)/in^3
3. Fuel consumption in gallons/mile
4. Significance: * = 0.05
   ** = 0.01
   *** = 0.001
5. Group 1 - EPA Contract 68-01-2113
   Group 2 - EPA Contract 68-03-2147

The necessary regression analysis was performed on all data bases. The results are presented in Table 79. This table shows the regression coefficients for the relationship between each emission and vehicle weight and weight/CID. Within each emission, a separate equation is shown for each level of emission control. For CO, NO_x, and fuel consumption, the majority of the truck groups had regression equations that were significant. In addition, the coefficients of determination for these three variables are often above 0.600. It is probable that some of the data scatter in this analysis is due to the differences in emissions caused by engine model, as previously mentioned. It is not recommended that the HC equations be used to predict HC emissions with changes in vehicle weight. Whether the equations for the other three variables should be used is a matter of judgment.

The average test weights for data base 1 is shown in Table 66. The average test weight for the empty, half, and full load tests for each of the model year groups in data base 2 as well as the average test weight for all diesel trucks in the data base are given in Table 80.

TABLE 79. RESULTS OF REGRESSION ANALYSIS FOR EMISSIONS AND FUEL RATE AS A FUNCTION OF WEIGHT AND WEIGHT/CID FOR VARIOUS DIESEL TRUCK GROUPS

Group	Constant	Wt/1000	Wt/CID	r^2	Std. Err.	No. of Trucks
HC Emissions						
1. SARR Pre-1974 Diesel	7.647	-0.018 ± 0.066	-0.051 ± 0.042	0.234	2.275	10
2. 1974-1975 Diesel	3.506	0.059 ± 0.019	-0.025 ± 0.010	0.457*	0.901	15
3. Pre-1974 Diesel	6.567	-0.071 ± 0.046	0.015 ± 0.032	0.379*	1.556	18
4. 1975 California Diesel	2.420	-0.001 ± 0.003		0.156	0.098	3
CO Emissions						
1. SARR Pre-1974 Diesel	-12.528	-0.711 ± 0.390	1.001 ± 0.250	0.697*	13.533	10
2. 1974-1975 Diesel	-6.289	0.636 ± 0.236	0.067 ± 0.133	0.641**	11.449	15
3. Pre-1974 Diesel	8.497	0.724 ± 0.338	-0.131 ± 0.225	0.599**	11.478	18
4. 1975 California Diesel	4.200	0.086 ± 0.000		1.000***	0.000	3
NO_x Emissions						
1. SARR Pre-1974 Diesel	1.584	0.379 ± 0.141	0.039 ± 0.080	0.585*	4.887	10
2. 1974-1975 Diesel	4.202	0.699 ± 0.163	0.018 ± 0.092	0.787***	7.908	15
3. Pre-1974 Diesel	7.558	-0.745 ± 0.437	1.051 ± 0.304	0.656***	14.838	18
4. 1975 California Diesel	10.930	0.404 ± 0.073		0.969	2.523	3
Fuel Consumption						
1. SARR Pre-1974 Diesel	0.070	0.004 ± 0.001	-0.000 ± 0.000	0.879***	0.018	10
2. 1974-1975 Diesel	0.101	0.004 ± 0.001	-0.001 ± 0.000	0.783***	0.042	15
3. Pre-1974 Diesel	0.127	0.004 ± 0.001	-0.001 ± 0.000	0.903***	0.021	18
4. 1975 California Diesel	0.160	0.002 ± 0.000		0.986	0.008	3

Notes:
1. Equation form: $y = b_0 + b_1 \text{(weight/1000)} + b_2 \left(\text{(wt/1000)/CID}\right)$
2. Weight in pounds and CID in cubic inches
3. Fuel consumption in gallons/mile
4. Significance: * = 0.05
   ** = 0.01
   *** = 0.001
5. Group 1 - EPA Contract 68-01-2113
   Group 2 - EPA Contract 68-03-2147
   to 4

TABLE 80. AVERAGE TEST WEIGHTS FOR VARIOUS DIESEL TRUCK GROUPS FROM CONTRACT 68-03-2147

	Test Weight, lb		
	Empty Load	Half Load	Full Load
Pre-1974 Diesel	20920	39423	59093
1974-1975 Diesel	19403	35806	55209
1975 California Diesel	24504	49000	73513
All Diesel Trucks	30586	38715	58676
Average		39326	

V. GASOLINE WEIGHTING FACTOR DEVELOPMENT

This section covers the analysis done in an attempt to develop a set of weighting factors that could be applied to the 9-mode FTP test for heavy-duty gasoline-powered trucks which would relate the 9-mode BSFC to on-the-road fuel economy. Additional modes were to be considered if necessary. The data and results in this section and presented in mixed English-metric units since the data was furnished in that form.

Data Base

The data from the CRC CAPE-21 study was the primary data used in this analysis. There were 35 gasoline-powered trucks tested in New York City and 26 in Los Angeles. A description of the trucks is included in Appendix A. The CAPE-21 data used was in the form of a matrix for each truck showing percent time spent in a set of rpm and manifold vacuum intervals.

Approach

The basic approach was to attempt to develop weighting factors utilizing the present 9-mode test as much as possible, but also considering the addition of other modes that could be added to the present procedures with no change in test equipment and reasonable increases in test time. The first step would be to obtain the percent time matrices for each truck, together with descriptions of the trucks.

Once the mv-rpm matrices were assembled, they were divided by truck into groups by body style. The first question to be answered was: Can the current 9-mode procedure to used as is for a fuel consumption test, with possibly some reweighting of the modes? In other words, do the trucks operate enough of the time in the range covered by the 9-mode procedure? It should be kept in mind that the 9-mode procedure really has only five different mv-rpm modes plus idle. To determine if this is so, the percent time spent at the 9-mode speed and vacuum modes would be calculated for each truck along with the group average, maximum, minimum, range, standard deviation and coefficient of variation. Whether the 9-mode schedule can be used or not, weighting factors would be calculated from percent time in mode divided by total average percent time in all modes. If the average percentage time spent in these modes and the range and coefficient of variation are acceptable, then the present 9-mode schedule could be used with the calculated weighting factors. If the new weighting factors are close enough to the present weighting factors, consideration would be given to using the present factors.

It could be entirely possible that the current 9-modes would not cover a sufficient amount of the truck's operating time. If this is so, then other modes would be considered. The initial method of choosing the modes would be to try and add additional vacuum modes at 2000 rpm. If this did not yield sufficient average operating time and acceptable coefficients of variation, then additional vacuum modes at a single additional speed would be tried.

The assumption implicit in the above procedure is that if the BSFC from the various modes is weighted by the percent of time that mode is actually encountered on the road, then there will be a correlation between test BSFC and on-the-road fuel economy. It was recognized that some means of correlating the weighting factors resulting from this study with actual truck operation was needed. It is important to show that if an engine has a lower composite BSFC than another engine on the test stand, it will have a lower fuel consumption in actual transient operation in a truck. It was decided to use the data from EPA Contract 68-01-0472 to attempt this correlation. Under that contract, six gasoline engines were tested using the 9-mode FTP on an engine test stand obtaining both horsepower and fuel consumption for each mode. Thus, modal and composite BSFC's were available. These six engines were also installed in trucks and tested on a chassis dynamometer using the 1975 light-duty FTP. While the trucks were not all operated on the chassis dynamometer at the same inertia weight, the inertias were all close enough that the data should be usable.

Analysis

The first item of analysis was to obtain average percent-time matrices for all the CAPE-21 trucks and various sub-sets of the trucks. Table 81 shows the average percent-time matrix for all of the CAPE-21 gasoline trucks. Note that the manifold vacuum is in one inch of mercury intervals and the engine speed in 200 rpm intervals. The manifold vacuum and rpm values shown are for the midpoint of the interval. Tables 82, 83, and 84 contain the average percent time matrices for all Los Angeles trucks, Los Angeles single unit trucks, and Los Angeles tractor trailers, respectively. Tables 85, 86, and 87 contain the same information for the New York City trucks. Examining the two matrices containing the average percent time for all trucks in each city, it can be seen that the Los Angeles all-truck matrix shows a different pattern of operation than the New York all-truck matrix.

As an aid to visualizing the operational patterns from the two cities, Figures 25 and 26 show the Los Angeles and New York all-truck matrices with the percent operation time divided into intervals and shaded to enhance the distinction between intervals. Figure 27 shows which regions of the matrix are considered engine idle, closed throttle and wide open throttle (WOT) operation. Comparing Figures 25 and 26, the New York mv-rpm pattern does not show the large amount of operating time in the 2700 to 2900 rpm range seen in Los Angeles operation. The New York matrix indicates a large amount of time spent in the 900 to 1500 rpm range at 12 to 20 inches of mercury manifold vacuum, while the Los Angeles matrix shows a much smaller amount of time at these operating conditions.

These distinctly different operating patterns for the two cities make the development of 9-mode weighting factors that would be applicable nationwide more difficult. In an effort to understand these differences, some available data on time in various rpm intervals from the San Antonio Road Route studies and an EPA analysis of the Ethyl Truck and Bus Study (ETABS) were compared with the CAPE-21 data. In this case, the total time spent in each rpm interval for all manifold vacuums was calculated from the CAPE-21 data for both New York and Los Angeles. This comparison was also needed for Item 8 of Section III of this report and is shown in Table 28 of Section III. The rpm level indicated is the midpoint of the interval, except for the SARR data, where the indicated rpm is the upper limit of

TABLE 81. AVERAGE PERCENT TIME SPENT IN VARIOUS ENGINE RPM-MANIFOLD VACUUM CONDITIONS FOR ALL GASOLINE TRUCKS FROM LOS ANGELES AND NEW YORK

Engine Speed, 200 rpm Intervals	Manifold Vacuum, 1 inch of Hg Intervals																										
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.06	0.17	0.34	0.41	1.00	1.64	0.24	0.04	0.00	0.00	0.00	0.00	0.00	0.00
600	0.01	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.03	0.04	0.05	0.06	0.10	0.34	1.00	2.30	2.55	3.34	4.80	1.01	0.39	0.03	0.00	0.00	0.00	0.00
800	0.02	0.08	0.08	0.07	0.06	0.06	0.06	0.06	0.05	0.06	0.07	0.08	0.10	0.13	0.15	0.21	0.54	1.36	2.19	2.16	1.49	1.09	0.14	0.04	0.01	0.01	0.00
1000	0.04	0.11	0.12	0.10	0.10	0.09	0.09	0.09	0.09	0.10	0.12	0.12	0.18	0.26	0.50	0.20	0.23	0.39	0.59	1.18	1.90	1.64	0.55	0.14	0.04	0.01	0.00
1200	0.04	0.14	0.14	0.14	0.12	0.11	0.12	0.11	0.10	0.11	0.13	0.14	0.14	0.24	0.71	0.28	0.22	0.27	0.32	0.45	0.76	0.71	0.74	0.36	0.12	0.02	0.00
1400	0.04	0.16	0.16	0.16	0.15	0.13	0.13	0.13	0.13	0.13	0.15	0.14	0.17	0.18	0.26	0.26	0.28	0.27	0.27	0.29	0.41	0.43	0.65	0.53	0.24	0.03	0.00
1600	0.06	0.20	0.20	0.17	0.15	0.14	0.14	0.14	0.14	0.14	0.17	0.16	0.18	0.20	0.25	0.24	0.25	0.31	0.26	0.29	0.33	0.35	0.50	0.56	0.37	0.07	0.00
1800	0.05	0.22	0.25	0.19	0.16	0.15	0.16	0.15	0.14	0.14	0.16	0.17	0.20	0.21	0.25	0.25	0.25	0.27	0.31	0.22	0.22	0.29	0.35	0.48	0.39	0.11	0.00
2000	0.05	0.22	0.31	0.20	0.16	0.14	0.15	0.16	0.14	0.14	0.16	0.17	0.25	0.25	0.31	0.33	0.29	0.27	0.21	0.25	0.19	0.24	0.26	0.39	0.34	0.14	0.01
2200	0.04	0.22	0.33	0.24	0.17	0.15	0.14	0.14	0.14	0.14	0.17	0.17	0.21	0.20	0.23	0.20	0.31	0.18	0.16	0.25	0.15	0.19	0.20	0.26	0.28	0.14	0.02
2400	0.02	0.24	0.43	0.35	0.20	0.17	0.17	0.16	0.15	0.17	0.21	0.21	0.21	0.21	0.23	0.21	0.19	0.18	0.14	0.14	0.13	0.16	0.17	0.20	0.22	0.13	0.02
2600	0.01	0.19	0.65	0.53	0.28	0.23	0.22	0.21	0.20	0.22	0.29	0.29	0.30	0.27	0.28	0.24	0.19	0.19	0.14	0.13	0.13	0.14	0.13	0.15	0.16	0.09	0.01
2800	0.00	0.12	0.71	0.63	0.39	0.30	0.25	0.22	0.21	0.23	0.28	0.27	0.30	0.28	0.29	0.25	0.21	0.19	0.13	0.11	0.12	0.12	0.11	0.11	0.10	0.06	0.01
3000	0.00	0.08	0.41	0.37	0.26	0.19	0.14	0.11	0.11	0.13	0.15	0.16	0.18	0.17	0.19	0.16	0.13	0.12	0.08	0.07	0.07	0.07	0.07	0.06	0.05	0.03	0.00
3200	0.00	0.04	0.18	0.15	0.12	0.06	0.05	0.05	0.05	0.05	0.06	0.06	0.07	0.09	0.08	0.06	0.05	0.05	0.04	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.00
3400	0.00	0.02	0.07	0.06	0.07	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.00
3600	0.00	0.01	0.04	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00
3800	0.00	0.00	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
4000	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4200	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 82. AVERAGE PERCENT TIME SPENT IN VARIOUS ENGINE RPM-MANIFOLD VACUUM CONDITIONS FOR ALL 26 GASOLINE TRUCKS FROM LOS ANGELES CAPE-21 STUDY

Engine Speed, 200 rpm Intervals	Manifold Vacuum, 1 Inch of Hg, Intervals																										
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.04	0.03	0.04	0.10	0.08	0.12	0.06	0.00	0.00	0.00	0.00	0.00	0.00
600	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.08	0.19	0.47	1.14	2.03	3.59	0.77	0.85	0.02	0.01	0.00	0.00	0.00
800	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.04	0.05	0.06	0.08	0.11	0.34	0.56	0.77	1.27	1.09	1.82	0.20	0.03	0.03	0.00	0.00
1000	0.10	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.07	0.09	0.10	0.12	0.18	0.24	0.56	1.18	2.59	0.66	0.16	0.05	0.03	0.00
1200	0.01	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.06	0.07	0.07	0.07	0.08	0.10	0.11	0.12	0.17	0.19	0.22	0.31	0.70	0.79	0.37	0.16	0.04	0.00
1400	0.01	0.10	0.11	0.09	0.09	0.08	0.84	0.07	0.07	0.07	0.09	0.09	0.10	0.11	0.13	0.14	0.14	0.19	0.19	0.21	0.27	0.34	0.56	0.54	0.33	0.07	0.01
1600	0.01	0.13	0.18	0.14	0.13	0.12	0.10	0.10	0.07	0.09	0.12	0.14	0.14	0.16	0.17	0.21	0.19	0.23	0.19	0.20	0.26	0.30	0.42	0.59	0.44	0.15	0.01
1800	0.00	0.14	0.27	0.18	0.17	0.15	0.15	0.13	0.12	0.12	0.16	0.18	0.25	0.24	0.26	0.28	0.28	0.31	0.21	0.19	0.25	0.24	0.35	0.49	0.48	0.21	0.01
2000	0.00	0.16	0.41	0.22	0.18	0.17	0.18	0.18	0.14	0.14	0.19	0.22	0.40	0.37	0.48	0.54	0.47	0.42	0.24	0.20	0.22	0.25	0.31	0.38	0.47	0.25	0.02
2200	0.00	0.22	0.50	0.33	0.22	0.19	0.18	0.17	0.16	0.15	0.20	0.23	0.31	0.29	0.31	0.28	0.25	0.27	0.21	0.19	0.18	0.21	0.26	0.29	0.41	0.25	0.05
2400	0.00	0.31	0.76	0.62	0.33	0.28	0.27	0.26	0.23	0.25	0.33	0.34	0.33	0.33	0.34	0.34	0.29	0.29	0.22	0.20	0.19	0.18	0.25	0.23	0.35	0.22	0.05
2600	0.00	0.22	1.29	1.08	0.54	0.44	0.42	0.39	0.39	0.42	0.56	0.56	0.56	0.49	0.51	0.45	0.35	0.35	0.25	0.22	0.20	0.19	0.21	0.19	0.26	0.17	0.03
2800	0.00	0.09	1.44	1.33	0.82	0.63	0.51	0.45	0.43	0.45	0.58	0.54	0.61	0.55	0.58	0.52	0.42	0.37	0.25	0.21	0.20	0.19	0.19	0.13	0.18	0.12	0.01
3000	0.00	0.04	0.70	0.72	0.52	0.37	0.27	0.19	0.21	0.25	0.30	0.31	0.37	0.35	0.39	0.33	0.27	0.24	0.17	0.13	0.13	0.10	0.09	0.07	0.09	0.07	0.00
3200	0.00	0.02	0.21	0.21	0.23	0.11	0.08	0.08	0.08	0.09	0.12	0.12	0.13	0.17	0.16	0.13	0.11	0.11	0.08	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.00
3400	0.00	0.17	0.08	0.06	0.12	0.06	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.05	0.05	0.05	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.03	0.00
3600	0.00	0.00	0.07	0.04	0.05	0.05	0.02	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.10	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.00
3800	0.00	0.00	0.07	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.21	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
4000	0.00	0.00	0.01	0.04	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
4200	0.00	0.00	0.00	0.01	0.03	0.03	0.03	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4400	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Headings are midpoint of interval

TABLE 83. AVERAGE PERCENT TIME SPENT IN VARIOUS ENGINE RPM-MANIFOLD VACUUM CONDITIONS FOR TWENTY SINGLE UNIT GASOLINE TRUCKS FROM LOS ANGELES CAPE-21 STUDY

Engine Speed, 2000 rpm Intervals	Manifold Vacuum, 1 inch of Hg, Intervals																										
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
200	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
400	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,03	0,05	0,03	0,03	0,08	0,04	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00
600	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,02	0,03	0,04	0,09	0,22	0,45	0,97	2,26	4,19	0,87	1,08	0,02	0,00	0,00	0,00	0,00
800	0,01	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,04	0,06	0,06	0,08	0,12	0,40	0,64	0,82	1,33	1,16	1,87	0,20	0,03	0,00	0,00	0,00
1000	0,01	0,06	0,05	0,05	0,06	0,05	0,05	0,05	0,05	0,04	0,06	0,05	0,06	0,07	0,09	0,10	0,12	0,17	0,24	0,35	1,03	2,49	0,74	0,18	0,04	0,00	0,00
1200	0,01	0,10	0,09	0,08	0,09	0,07	0,07	0,07	0,06	0,06	0,07	0,08	0,07	0,09	0,10	0,11	0,12	0,16	0,20	0,21	0,31	0,74	0,90	0,43	0,19	0,01	0,00
1400	0,01	0,12	0,12	0,11	0,11	0,10	0,10	0,08	0,08	0,08	0,11	0,11	0,11	0,12	0,14	0,16	0,15	0,17	0,20	0,23	0,29	0,37	0,63	0,63	0,38	0,07	0,00
1600	0,01	0,14	0,19	0,16	0,16	0,14	0,12	0,12	0,11	0,11	0,15	0,16	0,07	0,18	0,19	0,23	0,20	0,22	0,20	0,23	0,29	0,35	0,47	0,69	0,49	0,18	0,00
1800	0,00	0,14	0,29	0,21	0,20	0,19	0,18	0,15	0,14	0,14	0,20	0,20	0,22	0,26	0,25	0,25	0,23	0,26	0,23	0,23	0,28	0,28	0,42	0,57	0,51	0,25	0,02
2000	0,00	0,13	0,44	0,26	0,21	0,21	0,21	0,18	0,15	0,16	0,22	0,23	0,23	0,26	0,30	0,27	0,25	0,26	0,25	0,22	0,24	0,29	0,37	0,44	0,48	0,26	0,34
2200	0,00	0,12	0,49	0,38	0,26	0,22	0,20	0,19	0,18	0,17	0,23	0,25	0,25	0,25	0,28	0,25	0,23	0,25	0,22	0,20	0,19	0,22	0,30	0,34	0,40	0,23	0,06
2400	0,00	0,12	0,54	0,71	0,36	0,32	0,29	0,29	0,26	0,28	0,36	0,37	0,37	0,36	0,37	0,37	0,31	0,32	0,24	0,21	0,20	0,20	0,27	0,27	0,35	0,19	0,59
2600	0,00	0,11	0,60	1,21	0,57	0,46	0,43	0,42	0,43	0,46	0,62	0,62	0,64	0,54	0,53	0,48	0,36	0,37	0,27	0,22	0,20	0,17	0,21	0,21	0,26	0,15	0,03
2800	0,00	0,06	0,56	1,40	0,84	0,66	0,50	0,45	0,43	0,47	0,61	0,59	0,69	0,60	0,61	0,55	0,43	0,38	0,25	0,21	0,19	0,15	0,17	0,15	0,16	0,11	0,02
3000	0,00	0,02	0,29	0,68	0,54	0,36	0,25	0,18	0,22	0,27	0,34	0,35	0,44	0,41	0,45	0,37	0,30	0,26	0,18	0,14	0,12	0,09	0,09	0,07	0,09	0,05	0,01
3200	0,00	0,01	0,12	0,18	0,24	0,10	0,07	0,08	0,08	0,09	0,12	0,13	0,16	0,20	0,19	0,14	0,12	0,12	0,09	0,07	0,06	0,05	0,05	0,04	0,04	0,02	0,00
3400	0,00	0,00	0,05	0,05	0,13	0,06	0,03	0,02	0,03	0,04	0,04	0,05	0,06	0,05	0,05	0,05	0,04	0,04	0,04	0,02	0,02	0,02	0,01	0,01	0,01	0,00	0,00
3600	0,00	0,00	0,02	0,02	0,04	0,04	0,01	0,00	0,01	0,01	0,01	0,01	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3800	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4000	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4200	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4400	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Note: Headings are midpoint of interval

TABLE 84. AVERAGE PERCENT TIME SPENT IN VARIOUS ENGINE RPM-MANIFOLD VACUUM CONDITIONS FOR SIX GASOLINE TRACTOR-TRAILERS FROM LOS ANGELES CAPE-21 STUDY

Engine Speed, 200 rpm Intervals	Manifold Vacuum, 1 Inch of Hg, Intervals																										
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
200	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
400	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,30	0,00	0,00	0,00	0,03	0,04	0,08	0,13	0,22	0,45	0,24	0,00	0,00	0,00	0,00	0,00	0,00
600	0,00	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,04	0,08	0,52	1,72	1,28	1,60	0,45	0,09	0,05	0,04	0,00	0,00	0,00
800	0,00	0,02	0,02	0,02	0,02	0,01	0 02	0,02	0,02	0,02	0,03	0,03	0,03	0,05	0,07	0,09	0,13	0,26	0,63	1,06	0,87	1,66	0,11	0,06	0,12	0,00	0,00
1000	0,01	0,04	0,04	0,03	0,03	0,20	0,02	0,03	0,03	0,03	0,05	0,05	0,05	0,06	0,08	0,12	0,13	0,22	0,22	1,25	1,69	2,91	0,37	0,07	0,09	0,11	0,00
1200	0,00	0,04	0,05	0,03	0,03	0,02	0,04	0,03	0,02	0,04	0,05	0,05	0,05	0,07	0,09	0,12	0,14	0,22	0,17	0,21	0,31	0,59	0,43	0,17	0,09	0,13	0,00
1400	0,30	0,05	0,06	0,04	0,03	0,02	0,03	0,03	0,02	0,03	0,05	0,05	0,05	0,07	0,09	0,10	0,13	0,24	0,13	0,13	0,17	0,22	0,31	0,24	0,18	0,05	0,03
1600	0,00	0,09	0,14	0,05	0,04	0,03	0,05	0,04	0,03	0,04	0,04	0,05	0,06	0,07	0,11	0,14	0,18	0,29	0,13	0,11	0,16	0,14	0,23	0,24	0,29	0,06	0,03
1800	0,00	0,14	0,21	0,08	0,06	0,04	0,07	0,05	0,05	0,05	0,06	0,11	0,36	0,21	0,30	0,37	0,43	0,50	0,16	0,09	0,16	0,13	0,14	0,28	0,40	0,07	0,01
2000	0,00	0,28	0,33	0,12	0,08	0,07	0,12	0,18	0,11	0,08	0,11	0,22	0,97	0,74	1,08	1,43	1,25	0,97	0,22	0,16	0,15	0,13	0,13	0,21	0,43	0,23	0,00
2200	0,00	0,55	0,55	0,17	0,11	0,11	0,12	0,11	0,11	0,11	0,13	0,18	0,48	0,42	0,43	0,36	0,30	0,35	0,17	0,16	0,16	0,17	0,15	0,13	0,42	0,29	0,01
2400	0,00	0,92	1,49	0,35	0,22	0,17	0,19	0,15	0,14	0,15	0,22	0,23	0,20	0,22	0,24	0,28	0,23	0,23	0,17	0,16	0,16	0,14	0,18	0,12	0,37	0,31	0,02
2600	0,00	0,57	3,56	0,66	0,46	0,37	0,40	0,33	0,26	0,28	0,36	0,39	0,33	0,35	0,42	0,37	0,31	0,29	0,19	0,20	0,20	0,23	0,22	0,11	0,27	0,23	0,27
2800	0,00	0,21	4,38	1,15	0,75	0,56	0,57	0,47	0,40	0,38	0,47	0,39	0,34	0,37	0,47	0,43	0,37	0,35	0,23	0,21	0,27	0,33	0,24	0,09	0,22	0,19	0,02
3000	0,00	0,13	2,07	0,86	0,47	0,40	0,33	0,25	0,19	0,19	0,18	0,18	0,13	0,14	0,17	0,20	0,17	0,18	0,12	0,12	0,15	0,16	0,12	0,06	0,12	0,16	0,01
3200	0,00	0,07	0,51	0,30	0,20	0,15	0,11	0,08	0,06	0,07	0,09	0,08	0,06	0,07	0,09	0,08	0,06	0,06	0,04	0,04	0,04	0,05	0,06	0,03	0,05	0,12	0,01
3400	0,00	0,07	0,18	0,09	0,06	0,06	0,06	0,05	0,05	0,06	0,09	0,07	0,05	0,05	0,04	0,05	0,05	0,03	0,02	0,03	0,03	0,03	0,03	0,01	0,03	0,09	0,00
3600	0,00	0,01	0,25	0,10	0,06	0,07	0,08	0,05	0,05	0,06	0,09	0,08	0,06	0,06	0,05	0,05	0,03	0,04	0,02	0,03	0,02	0,02	0,02	0,01	0,03	0,08	0,01
3800	0,00	0,00	0,28	0,15	0,10	0,09	0,12	0,08	0,07	0,07	0,09	0,08	0,06	0,06	0,06	0,05	0,04	0,03	0,02	0,03	0,02	0,02	0,02	0,01	0,02	0,04	0,01
4000	0,00	0,00	0,02	0,17	0,09	0,05	0,08	0,06	0,06	0,07	0,08	0,07	0,07	0,05	0,05	0,04	0,02	0,02	0,01	0,02	0,01	0,01	0,02	0,05	0,01	0,02	0,00
4200	0,00	0,00	0,00	0,04	0,12	0,11	0,11	0,07	0,06	0,08	0,09	0,09	0,05	0,05	0,04	0,03	0,02	0,01	0,01	0,01	0,01	0,01	0,00	0,00	0,00	0,01	0,00
4400	0,00	0,00	0,00	0,00	0,01	0,02	0,03	0,02	0,01	0,02	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Note: Headings are midpoint of interval

TABLE 85. AVERAGE PERCENT TIME SPENT IN VARIOUS ENGINE RPM-MANIFOLD VACUUM CONDITIONS
FOR ALL 35 GASOLINE TRUCKS FROM NEW YORK CAPE-21 STUDY

Engine Speed, 200 rpm Intervals	Manifold Vacuum, 1 Inch of Hg. Intervals																										
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	24
200	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.15	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.06	0.09	0.26	0.57	0.68	1.67	2.80	0.32	0.03	0.00	0.00	0.00	0.00	0.00	0.00
600	0.02	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.04	0.04	0.05	0.06	0.09	0.14	0.54	1.61	3.65	3.59	4.30	5.70	1.19	0.05	0.04	0.00	0.00	0.00	0.00
800	0.03	0.11	0.11	0.09	0.09	0.08	0.08	0.08	0.07	0.08	0.09	0.11	0.13	0.18	0.20	0.28	0.69	1.95	3.24	2.85	1.79	0.56	0.11	0.04	0.00	0.00	0.00
1000	0.05	0.15	0.18	0.15	0.13	0.12	0.13	0.13	0.12	0.14	0.17	0.17	0.27	0.41	0.80	0.27	0.31	0.53	0.85	1.64	2.44	0.94	0.47	0.12	0.03	0.00	0.00
1200	0.06	0.18	0.19	0.19	0.15	0.14	0.15	0.15	0.14	0.16	0.18	0.19	0.20	0.35	1.17	0.41	0.30	0.35	0.42	0.62	1.10	0.71	0.70	0.35	0.08	0.00	0.00
1400	0.07	0.21	0.20	0.21	0.19	0.16	0.17	0.17	0.17	0.18	0.20	0.18	0.22	0.24	0.37	0.35	0.38	0.33	0.34	0.35	0.52	0.51	0.71	0.53	0.17	0.00	0.00
1600	0.08	0.25	0.22	0.20	0.17	0.16	0.17	0.17	0.18	0.17	0.20	0.18	0.21	0.23	0.31	0.27	0.30	0.37	0.31	0.35	0.39	0.39	0.55	0.54	0.32	0.01	0.00
1800	0.08	0.27	0.24	0.20	0.16	0.16	0.17	0.16	0.15	0.16	0.15	0.16	0.17	0.19	0.24	0.24	0.23	0.25	0.37	0.24	0.20	0.32	0.35	0.47	0.32	0.03	0.00
2000	0.09	0.26	0.24	0.18	0.14	0.12	0.13	0.14	0.14	0.14	0.14	0.13	0.13	0.15	0.19	0.17	0.15	0.15	0.19	0.28	0.17	0.24	0.22	0.32	0.24	0.05	0.00
2200	0.07	0.23	0.21	0.17	0.13	0.11	0.11	0.11	0.12	0.13	0.14	0.13	0.14	0.13	0.17	0.14	0.36	0.12	0.12	0.30	0.13	0.17	0.15	0.24	0.19	0.06	0.00
2400	0.04	0.19	0.18	0.14	0.10	0.09	0.09	0.09	0.09	0.10	0.12	0.12	0.12	0.13	0.15	0.12	0.11	0.10	0.09	0.09	0.09	0.14	0.10	0.17	0.12	0.06	0.00
2600	0.02	0.18	0.18	0.12	0.09	0.08	0.08	0.07	0.07	0.07	0.09	0.09	0.10	0.11	0.11	0.09	0.08	0.07	0.96	0.06	0.08	0.10	0.07	0.13	0.08	0.03	0.00
2800	0.01	0.14	0.18	0.11	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.06	0.05	0.05	0.04	0.04	0.05	0.06	0.06	0.10	0.04	0.02	0.00
3000	0.00	0.11	0.19	0.11	0.06	0.05	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.03	0.04	0.04	0.06	0.02	0.00	0.00
3200	0.00	0.06	0.17	0.10	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.01	0.00	0.00
3400	0.00	0.02	0.06	0.06	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.00	0.00	0.00
3600	0.00	0.01	0.02	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00
3800	0.00	0.00	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
4000	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4200	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Headings are midpoint of interval

TABLE [illegible]. AVERAGE PERCENT OF TIME SPENT IN VARIOUS ENGINE RPM-MANIFOLD VACUUM CONDITIONS FOR 11 SINGLE UNIT GASOLINE TRUCKS FROM NEW YORK CAPE-21 STUDY

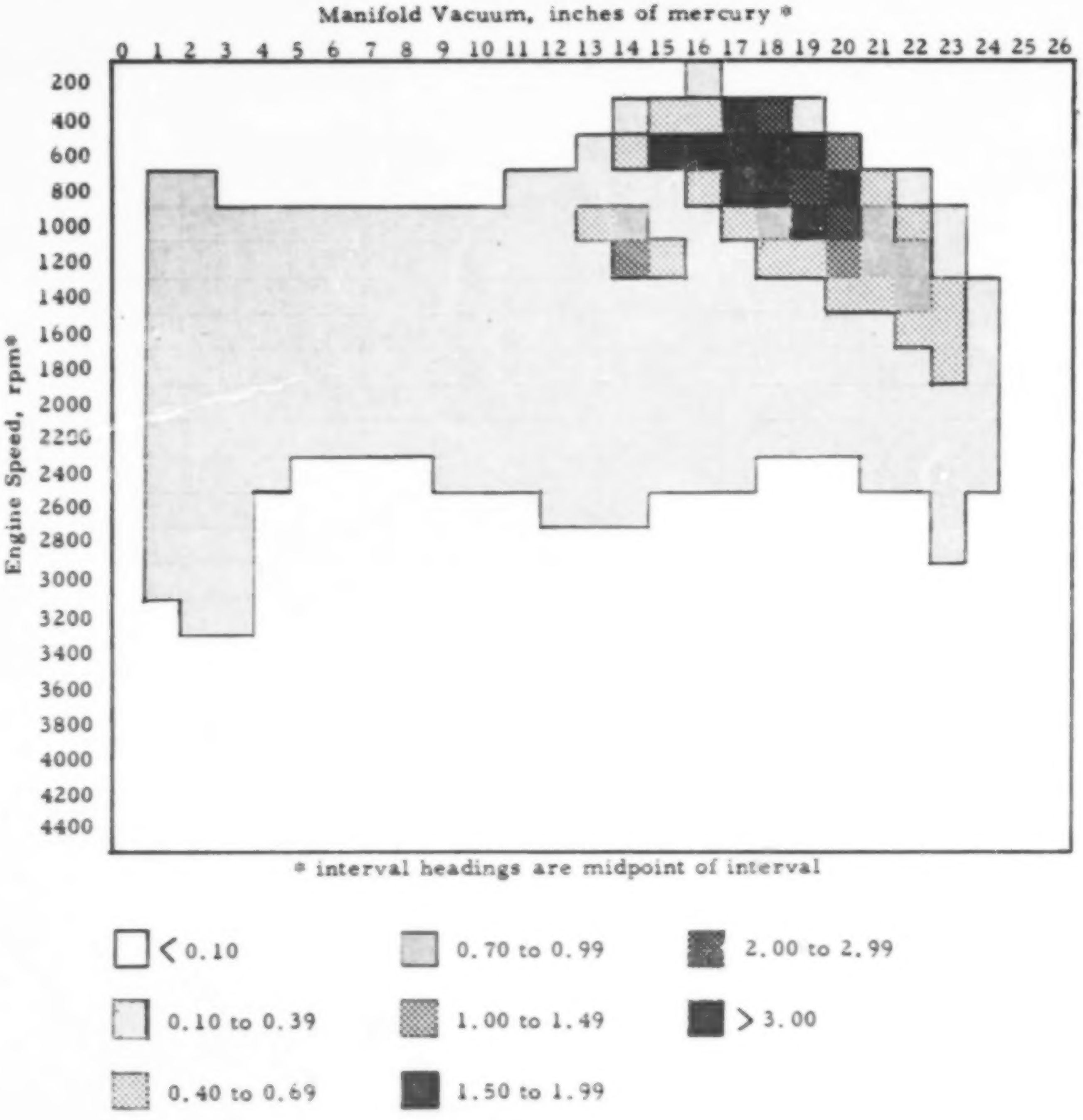
Engine Speed, 2000 rpm intervals	Manifold Vacuum, 1 Inch of Hg, Intervals																										
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
200	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.17	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.06	0.09	0.28	0.63	0.74	1.69	1.74	0.06	0.03	0.01	0.00	0.00	0.00	0.00	0.00
600	0.02	0.06	0.05	0.05	0.05	0.03	0.04	0.04	0.64	0.04	0.05	0.07	0.09	0.15	0.59	1.79	4.06	3.90	4.22	5.47	1.06	0.05	0.05	0.03	0.50	0.05	0.00
800	0.04	0.12	0.11	0.10	0.10	0.08	0.08	0.08	0.08	0.08	0.09	0.11	0.13	0.19	0.20	0.28	0.73	2.13	3.41	2.60	1.63	0.54	0.11	0.04	0.00	0.00	0.00
1000	0.06	0.16	0.17	0.15	0.13	0.12	0.13	0.13	0.13	0.14	0.16	0.17	0.28	0.44	0.86	0.25	0.31	0.54	0.86	1.70	2.59	0.97	0.45	0.12	0.03	0.00	0.00
1200	0.07	0.19	0.19	0.19	0.15	0.14	0.16	0.16	0.15	0.16	0.18	0.18	0.20	0.37	1.27	0.41	0.29	0.33	0.38	0.61	1.14	0.74	0.69	0.36	0.08	0.06	0.00
1400	0.08	0.23	0.22	0.21	0.19	0.17	0.18	0.19	0.18	0.18	0.20	0.18	0.23	0.24	0.37	0.36	0.39	0.32	0.29	0.30	0.54	0.54	0.73	0.52	0.19	0.00	0.00
1600	0.09	0.28	0.24	0.21	0.18	0.17	0.19	0.18	0.19	0.18	0.21	0.18	0.21	0.23	0.30	0.25	0.29	0.37	0.29	0.29	0.39	0.41	0.57	0.54	0.36	0.01	0.00
1800	0.09	0.30	0.26	0.22	0.17	0.17	0.19	0.18	0.16	0.17	0.17	0.17	0.18	0.20	0.25	0.23	0.22	0.23	0.36	0.23	0.20	0.14	0.35	0.47	0.36	0.32	0.00
2000	0.10	0.28	0.26	0.20	0.15	0.13	0.14	0.16	0.15	0.15	0.15	0.14	0.15	0.17	0.21	0.19	0.16	0.15	0.17	0.31	0.17	0.26	0.23	0.31	0.27	0.06	0.00
2200	0.08	0.23	0.22	0.18	0.13	0.12	0.12	0.12	0.14	0.14	0.15	0.15	0.15	0.14	0.19	0.15	0.40	0.12	0.11	0.33	0.14	0.18	0.16	0.21	0.21	0.07	0.00
2400	0.04	0.18	0.18	0.14	0.11	0.09	0.09	0.10	0.09	0.11	0.13	0.13	0.13	0.13	0.16	0.13	0.11	0.11	0.09	0.10	0.09	0.15	0.10	0.14	0.13	0.06	0.00
2600	0.02	0.15	0.15	0.11	0.08	0.07	0.07	0.07	0.07	0.07	0.09	0.10	0.11	0.11	0.12	0.09	0.08	0.07	0.06	0.06	0.08	1.30	0.07	0.09	0.08	0.03	0.00
2800	0.01	0.10	0.11	0.09	0.06	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.05	0.05	0.04	0.04	0.04	0.05	0.06	0.05	0.06	0.04	0.02	0.00
3000	0.00	0.06	0.08	0.07	0.05	0.04	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.01	0.00	0.00
3200	0.00	0.04	0.07	0.06	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.02	0.02	0.01	0.00	0.00
3400	0.00	0.02	0.05	0.04	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
3600	0.00	0.00	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
3800	0.00	0.00	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
4000	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4200	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Headings are midpoint of interval

TABLE 87. AVERAGE PERCENT TIME SPENT IN VARIOUS ENGINE RPM-MANIFOLD VACUUM CONDITIONS FOR FOUR GASOLINE TRACTOR-TRAILERS FROM NEW YORK CAPE-21 STUDY

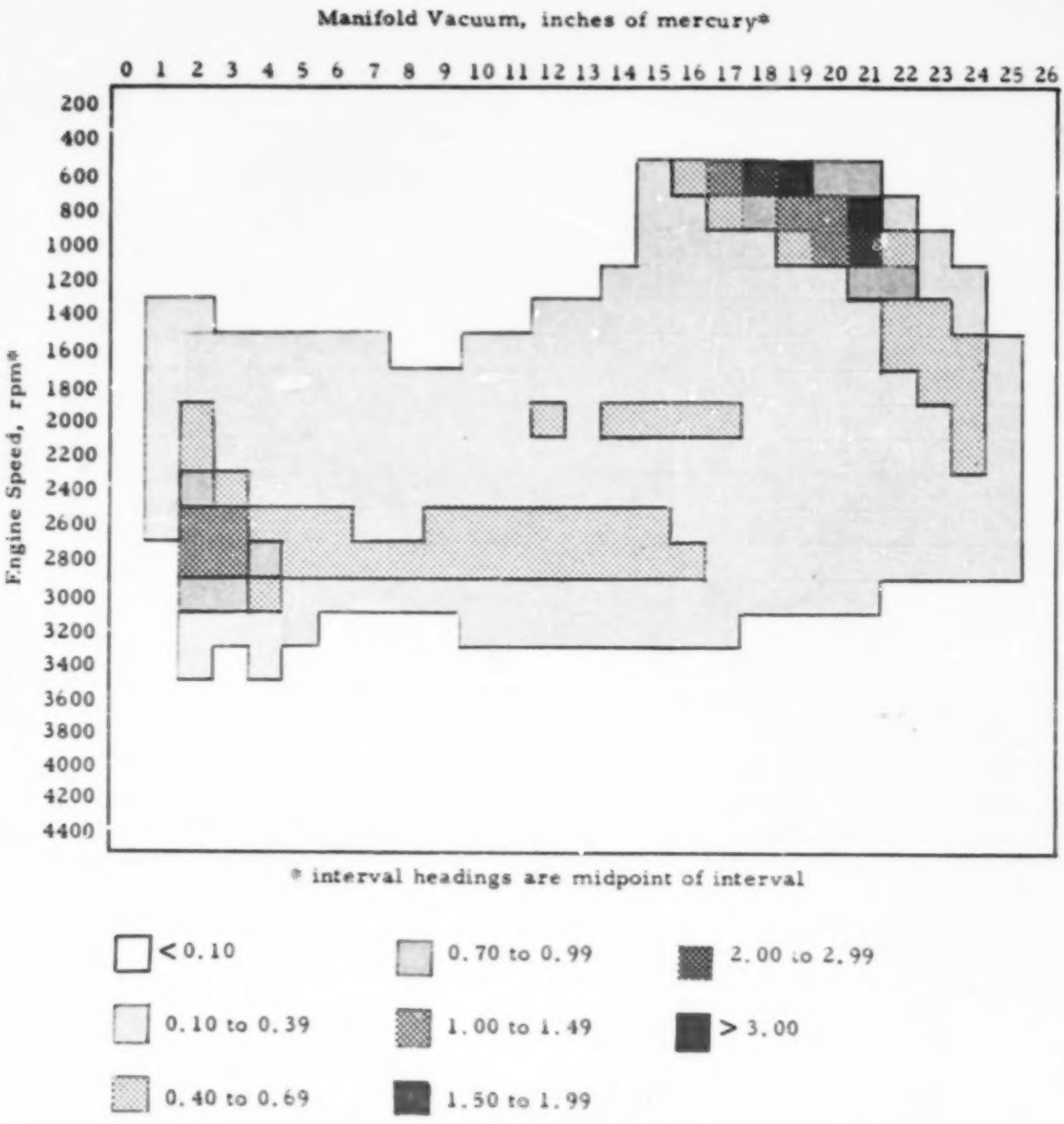
Engine Speed, 200 rpm Intervals	Manifold Vacuum, 1 Inch of Hg. Intervals 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
200	0,00	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
400	0,00	0,01	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,01	0,02	0,03	0,04	0,08	0,14	0,24	1,45	10,97	2,34	0,01	0,00	0,00	0,00	0,00	0,00	0,00
600	0,00	0,01	0,02	0,03	0,02	0,04	0,02	0,02	0,01	0,04	0,04	0,04	0,06	0,08	0,15	0,22	0,50	1,17	4,95	7,49	2,15	0,13	0,01	0,00	0,00	0,00	0,00
800	0,01	0,09	0,12	0,05	0,05	0,07	0,04	0,04	0,04	0,05	0,11	0,13	0,12	0,13	0,22	0,27	0,35	0,55	1,92	4,81	2,99	0,69	0,18	0,03	0,00	0,00	0,00
1000	0,01	0,08	0,25	0,12	0,14	0,13	0,10	0,08	0,06	0,11	0,24	0,19	0,16	0,19	0,35	0,36	0,37	0,52	0,73	1,13	1,27	0,74	0,65	0,13	0,03	0,00	0,00
1200	0,00	0,04	0,18	0,18	0,15	0,16	0,09	0,06	0,07	0,11	0,20	0,23	0,19	0,21	0,41	0,38	0,37	0,49	0,67	0,70	0,79	0,53	0,78	0,32	0,05	0,00	0,00
1400	0,00	0,05	0,11	0,23	0,17	0,12	0,08	0,05	0,10	0,13	0,17	0,15	0,16	0,22	0,34	0,29	0,34	0,41	0,67	0,80	0,41	0,26	0,62	0,60	0,06	0,00	0,00
1600	0,00	0,07	0,07	0,13	0,14	0,11	0,06	0,06	0,06	0,08	0,14	0,18	0,17	0,23	0,36	0,38	0,39	0,38	0,42	0,82	0,37	0,17	0,45	0,56	0,04	0,00	0,00
1800	0,00	0,07	0,06	0,07	0,07	0,07	0,05	0,05	0,05	0,06	0,06	0,08	0,07	0,09	0,16	0,25	0,34	0,41	0,46	0,33	0,21	0,13	0,30	0,49	0,05	0,01	0,00
2000	0,00	0,10	0,08	0,05	0,09	0,05	0,04	0,34	0,04	0,04	0,04	0,05	0,05	0,07	0,07	0,08	0,07	0,13	0,34	0,13	0,13	0,10	0,16	0,41	0,03	0,00	0,00
2200	0,00	0,16	0,15	0,09	0,06	0,07	0,05	0,04	0,04	0,04	0,04	0,04	0,04	0,06	0,06	0,06	0,08	0,08	0,16	0,09	0,07	0,07	0,10	0,49	0,02	0,00	0,00
2400	0,00	0,24	0,22	0,11	0,09	0,08	0,07	0,06	0,05	0,04	0,04	0,04	0,05	0,07	0,05	0,06	0,07	0,05	0,06	0,06	0,07	0,07	0,12	0,45	0,09	0,00	0,00
2600	0,00	0,38	0,40	0,18	0,15	0,17	0,11	0,08	0,07	0,05	0,07	0,06	0,06	0,07	0,06	0,06	0,06	0,06	0,06	0,07	0,06	0,67	0,14	0,45	0,10	0,00	0,00
2800	0,00	0,51	0,71	0,28	0,18	0,16	0,14	0,12	0,08	0,08	0,06	0,08	0,08	0,10	0,09	0,09	0,09	0,09	0,08	0,07	0,07	0,06	0,14	0,40	0,08	0,00	0,00
3000	0,01	0,45	1,07	0,43	0,21	0,17	0,13	0,12	0,07	0,07	0,05	0,05	0,05	0,06	0,06	0,06	0,06	0,06	0,05	0,05	0,04	0,05	0,13	0,28	0,05	0,00	0,00
3200	0,00	0,21	0,92	0,37	0,12	0,08	0,07	0,06	0,04	0,03	0,03	0,02	0,03	0,03	0,04	0,03	0,03	0,04	0,03	0,02	0,02	0,03	0,09	0,15	0,01	0,00	0,00
3400	0,00	0,02	0,11	0,23	0,14	0,10	0,08	0,07	0,05	0,04	0,04	0,03	0,03	0,02	0,01	0,01	0,02	0,01	0,01	0,01	0,01	0,02	0,07	0,09	0,01	0,00	0,00
3600	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,01	0,02	0,02	0,02	0,02	0,03	0,03	0,01	0,01	0,01	0,02	0,04	0,00	0,00	0,00
3800	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4000	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4200	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4400	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Note: Headings are midpoint of interval



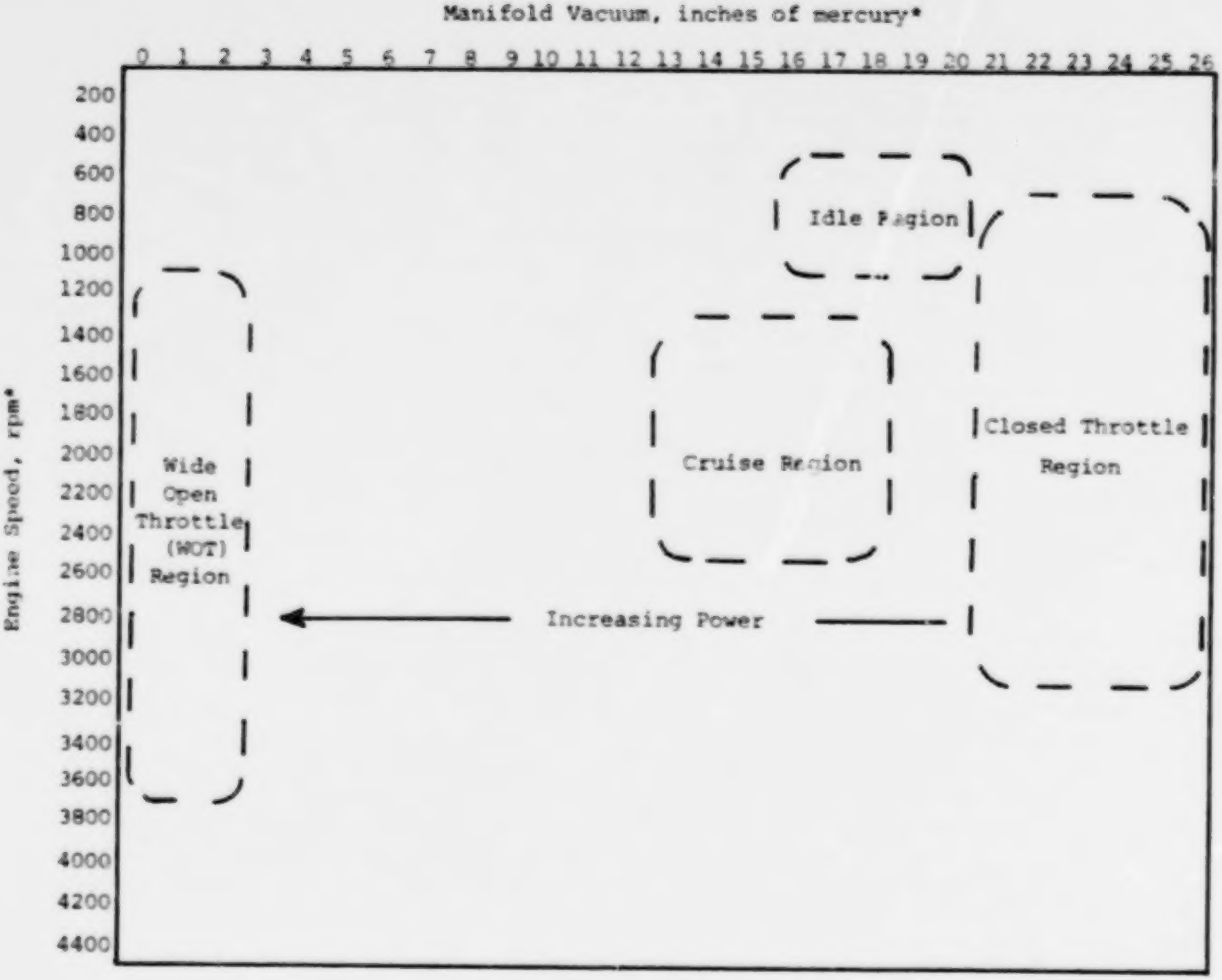
* interval headings are midpoint of interval

FIGURE 25. AVERAGE TIME SPENT IN VARIOUS ENGINE RPM MANIFOLD VACUUM CONDITIONS FOR ALL 35 GASOLINE TRUCKS IN NEW YORK CAPE-21 STUDY



* interval headings are midpoint of interval

FIGURE 26. AVERAGE TIME SPENT IN VARIOUS ENGINE RPM MANIFOLD VACUUM CONDITIONS FOR ALL 26 GASOLINE TRUCKS IN LOS ANGELES CAPE-21 STUDY


Manifold Vacuum, inches of mercury*
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Engine Speed, rpm*
200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000 4200 4400
Idle Region
Wide Open Throttle (WOT) Region
Cruise Region
Closed Throttle Region
Increasing Power

*interval headings are midpoint of intervals

FIGURE 27. MANIFOLD VACUUM - ENGINE RPM MATRIX SHOWING ENGINE OPERATING AREAS IN TERMS OF THROTTLE POSITION

the interval. The ETABS data which is the average of all trucks from three cities (Detroit, Los Angeles, and San Francisco) agree well with the New York CAPE-21 data, but there is no other agreement among the data sets.

Since there is a difference in the mv-rpm patterns for New York and Los Angeles, the calculations for the 9-mode weighting factors were done for each city individually as well as for the combined data from both cities. However, before calculating the weighting factors, one of the basic questions to be resolved was just how large an rpm-manifold vacuum area should each mode be assumed to represent. At the extreme, the rpm interval from 1000 to 3000 rpm could be used with the manifold vacuum divided up among the five modes so that all the vacuum intervals are used. Originally it was planned that the modes would be defined as idle and five vacuum intervals in the 2000 rpm ± 200 rpm interval. The vacuum intervals were to be 2 to 4 inches, 8 to 12 inches, 14 to 18 inches, 18 to 20 inches and 20 to 26 inches (CT). Idle was to be determined by visual inspection of each truck's matrix. However, a cursory examination of Figures 25 and 26 revealed that if the rpm was restricted to 2000 ± 200, very little of the non-idle operating time would be accounted for.

The non-idle portion of the 9-mode test was originally conceived to represent part throttle accels, cruise, part throttle decels, full load, and closed throttle conditions.(20) The speed, 2000 rpm, was chosen as "typical" or "average". The question arises if all of the matrix must be covered to fulfill the intent of the 9-mode test or if there are smaller areas, that would account for an acceptable amount of operating time.

One way to increase the total time accounted for in the 9-mode analysis of the CAPE-21 data would be to widen the speed interval used. The manifold vacuum interval could also be increased. However, it is not known how far from the exact 9-mode conditions the intervals can be extended before the fuel consumption no longer qgrees closely with 9-mode conditions. Engine maps which show fuel consumption could be examined to determine just how much the operational area could be increased and still be represented by the 9-mode condition. To help in determining how large the interval could be, plots of fuel consumption versus engine rpm at various manifold vacuum levels have been constructed for four engines tested at SwRI under Contract EHS 70-110.

The engines mapped were a 1969 Dodge 318 CID V8, a 1969 Chevrolet 250 CID I6, a 1969 IHC 304 CID V8, and a 1969 Ford 300 CID I6. No claim is made that these are typical engines. They serve only as convenient examples. Since the purpose of fuel weighting factors is to compare engine-to-engine using BSFC, it is not necessary that the fuel rate duplicate that occuring on the road. What is necessary is that the slope of the manifold vacuum line be approximately the same for each engine over the rpm range considered. Thus, if one engine had a lower fuel rate at 10 inches vacuum and 2000 rpm, it would also have a lower fuel rate at 10 inches vacuum and all other engine speeds within the range considered.

Figures 28 through 31 show fuel consumption versus engine rpm for 3", 10", 16", and 19" manifold vacuum for all four engines. If the constant vacuum lines for all the engines had the same slope, then the

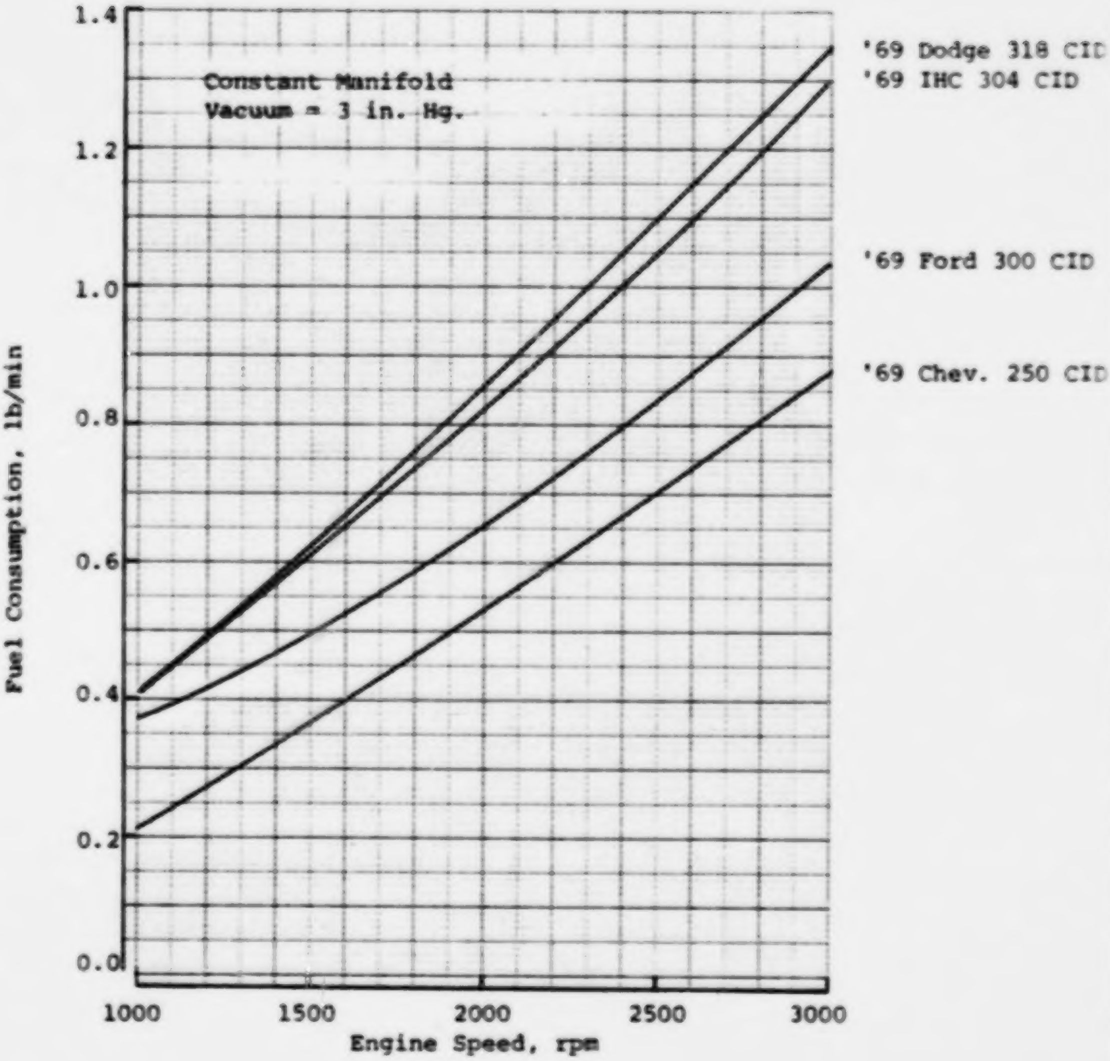


FIGURE 28. FUEL CONSUMPTION VERSUS ENGINE SPEED AT 3" INTAKE MANIFOLD VACUUM FOR FOUR ENGINES

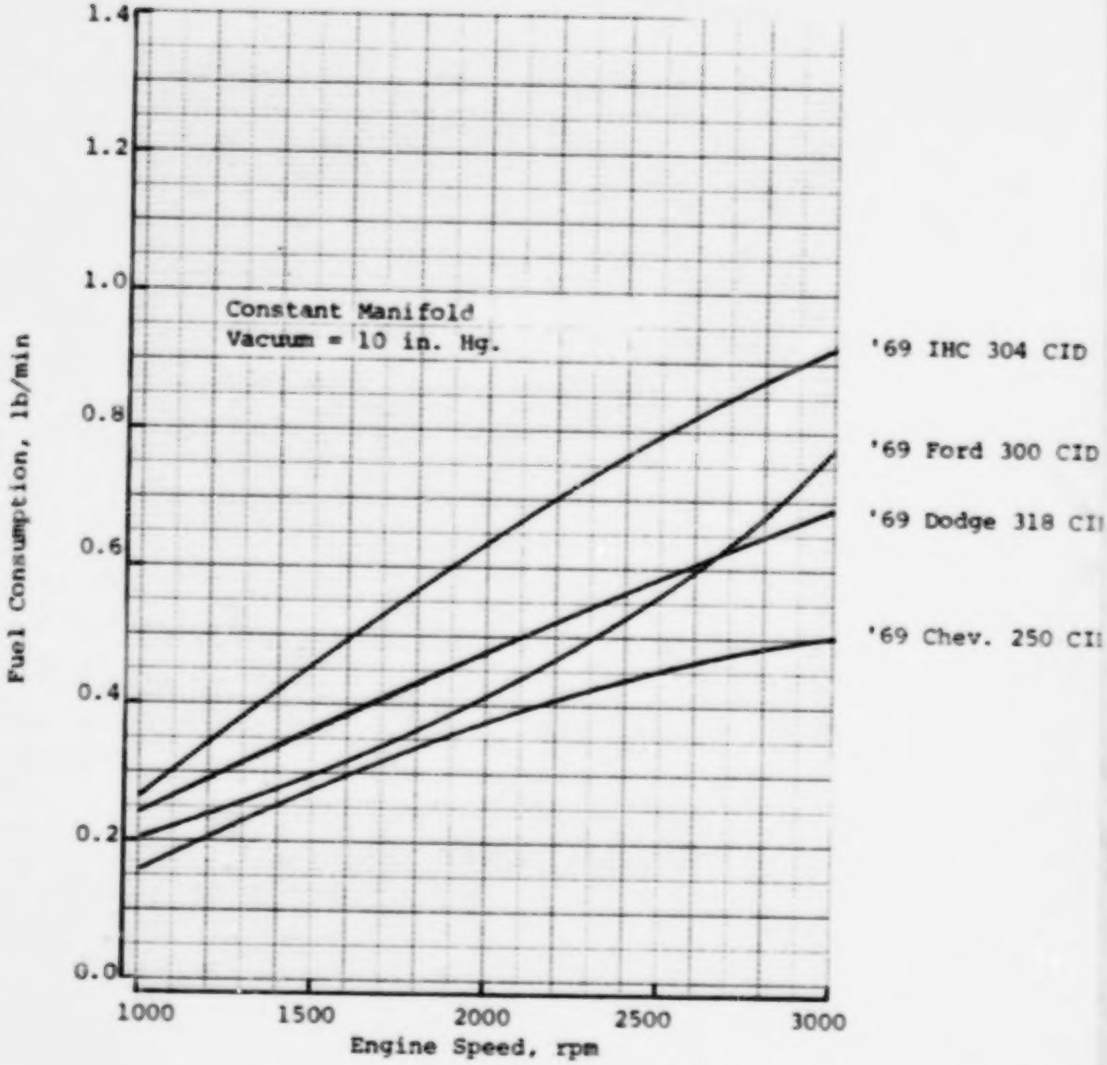


FIGURE 29. FUEL CONSUMPTION VERSUS ENGINE SPEED AT 10" INTAKE MANIFOLD VACUUM FOR FOUR ENGINES

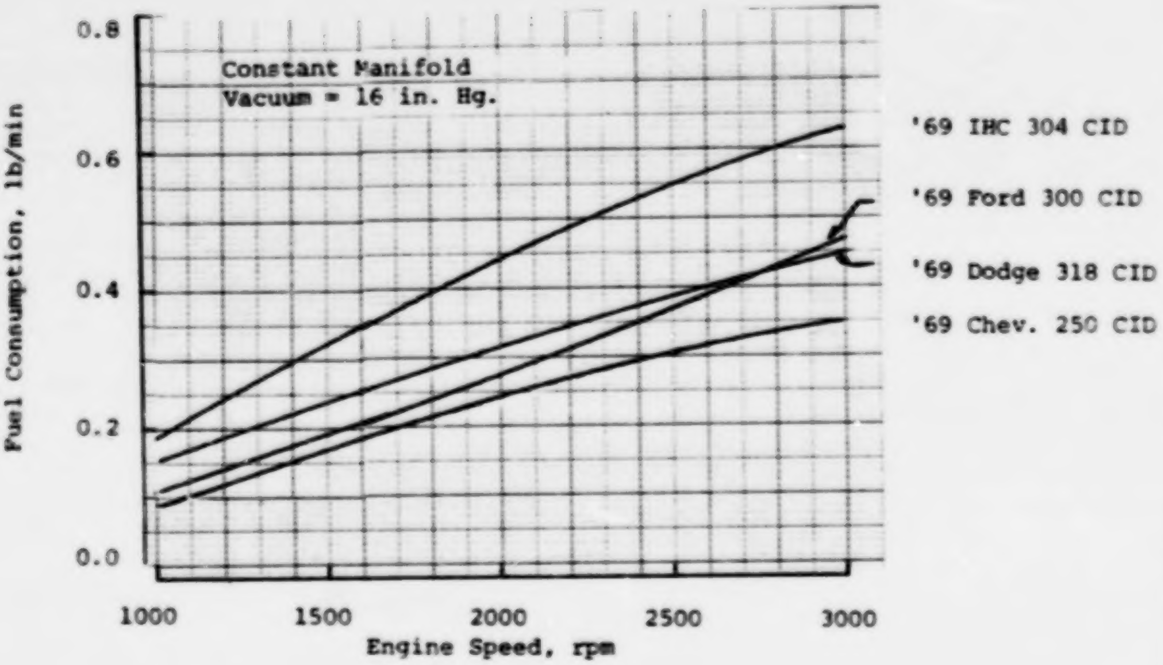


FIGURE 30. FUEL CONSUMPTION VERSUS ENGINE AT 16" INTAKE MANIFOLD VACUUM FOR FOUR ENGINES

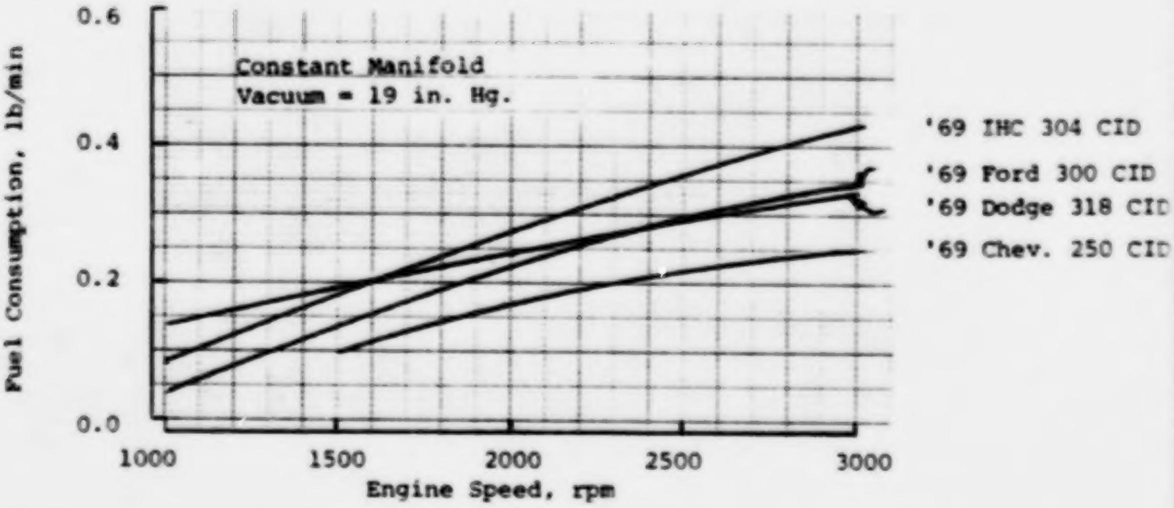


FIGURE 31. FUEL CONSUMPTION VERSUS ENGINE AT 19" INTAKE MANIFOLD VACUUM FOR FOUR ENGINES

2000 rpm fuel consumption comparison between trucks would hold at all other speeds. Then, the 2000 rpm speed of the 9-mode FTP could be used to compare fuel consumption of trucks, even if the majority of operating time was not at 2000 rpm.

The figures show differences in the slopes of the lines of constant vacuum. However, the slopes are, in general, reasonably similar except for the Ford engine at 10" vacuum and the Dodge at 19" vacuum. While this is an admittedly small selection of engines, it does lend some justification to extending the speed range represented by the 9-mode test.

The choice of the size of the rpm-manifold vacuum areas that should represent the modes of the 9-mode test were thus rather arbitrarily chosen to be a balance between using strictly the modal speed and vacuum point defined by the FTP and extending the areas to cover the entire operating region. Basically, the areas chosen, except for idle and closed throttle (CT), were ± 1.5 inches of mercury manifold vacuum either side of that specified by the 9-mode test, with an rpm interval from 1700 to 2900 rpm. The closed throttle area is from 20.5" to 26.5" manifold vacuum and 900 to 2100 rpm. The idle mode was the most subjective of the modes used. Since idle speed and manifold vacuum were not recorded when the trucks were tested, an exact definition of idle for each truck is not available.

The method used to determine idle operation for this analysis was to examine the rpm-mv matrix for each truck. Then, two or three cells were picked between 16" and 22" of vacuum and within the three speed intervals where the percent-time in the cell increased greatly from the time in adjacent cells. It was sometimes difficult to distinguish between idle and low speed closed throttle; but in general, the method appears to be satisfactory for this analysis.

The percent-time matrices from each truck were processed using a computer program written to choose the extended 9-mode conditions from the matrix for each truck and determine the average, minimum, and maximum time spent in each mode for the group of trucks processed. The resulting computer printouts showing both individual truck and average percent time spent in each of the modes for nine different groupings of the data are contained in Appendix D as Tables D-1 through D-9. Also shown are the minumum, maximum, and standard deviation for each group. The average percent-time in mode for each group is shown in Table 88.

The 9-mode weighting factors were then calculated from these average percent time-in-mode values. The percent time at idle is used as the idle weighting factor since it is assumed that all idle time in the operating matrix is used in determining the percent time at idle. Because the remaining modes do not represent all of the non-idle operation of the vehicle, the percent time-in-mode cannot be used as a weighting factor. However, if the total vehicle non-idle operating time is divided by the total time in the non-idle modes, a multiplication factor is obtained. This factor can be applied to the percent time in each of the non-idle modes to yield a weighting factor.

TABLE 88. CAPE-21 GASOLINE TRUCKS AVERAGE PERCENT TIME SPENT IN MODES OF 9-MODE FTP

	Average Percent Time in Mode						Total Percent Time
Data Base	Idle	C. T.	19"	16"	10"	3"	
NY+LA (All)	24.96	11.03	3.15	4.22	3.59	6.20	53.14
NY+LA (SU)*	25.69	11.68	3.19	3.85	3.81	5.69	53.98
NY+LA (TT)**	20.76	7.22	2.89	6.35	2.33	9.12	48.67
LA (All)	14.28	12.79	3.86	6.50	5.64	10.72	53.53
LA (SU)	15.15	14.21	4.01	5.72	6.17	9.94	55.20
LA (TT)	10.65	6.86	3.21	9.74	3.43	14.00	47.90
NY (All)	32.90	9.71	2.62	2.53	2.07	2.83	52.66
NY (SU)	32.83	9.97	2.64	2.58	2.21	2.81	53.05
NY (TT)	33.39	7.67	2.49	2.11	0.95	3.02	49.64

---

* SU-Single U
** TT- Tractor

This was done for each of the nine categories of trucks. The resulting 9-mode weighting factors are shown in Table 89. These weighting factors, then, are the 9-mode weighting factors representing the percent-time-in-mode experienced by the trucks tested in the CAPE-21 project. The current 9-mode heavy-duty FTP weighting factors are also shown for comparison.

As can be seen from the table, the differences between the New York and Los Angeles weighting factors in the idle, CT, and 3" modes for all trucks are greater than the difference between single unit and tractor-trailer trucks within either one of the cities. Since there is a greater difference between cities than between vehicle types within a city and information for weighting each city's driving patterns is not available, it is felt that the overall combined New York and Los Angeles weighting factors are probably the best ones to use.

Data from six engines tested under Contract 68-01-0472 were reprocessed using these new weighting factors as a "proof test" to determine if the new 9-mode BSFC would correlate with driving cycle fuel economy. The new composite 9-mode BSFC values are shown in Table 90, together with the BSFC values using the 9-mode FTP weighting factors for comparison. As can be seen from the table, the maximum BSFC difference using the two weighting factors is 4.5 percent (engine 6-0).

Also shown in the table is the normalized fuel economy (miles/gallon) from chassis dynamometer tests of trucks with these six engines installed driving the LA-4 driving cycle. It was necessary to normalize the fuel economy since the trucks were tested at different inertia settings. The fuel economy was normalized to 16,000 lb. A factor of 0.11 mpg/1000 lb was used to normalize the fuel economy (see Figure 31). The actual fuel economy for each truck is shown in Figure 32. The BSFC and mpg values shown in Table 90 are plotted as Figure 33 for better comparison. As can be seen from the figure, the 9-mode BSFC and the LA-4 fuel economy do not show a good correlation for either of the weighting factors. Part of the difficulty in using this data is the narrow range of BSFC and fuel economy of these six engines. However, this is the only known data that has both 9-mode BSFC and driving cycle fuel economy for the same engines.

At this point, it was requested that a new approach to the weighting factor problem be tried. This approach was based on obtaining weighting factors using the percent of fuel consumed accounted for by the 9-mode test rather than percent of time. The method used was to plot normalized fuel rate versus manifold vacuum of the four gasoline engines mapped under Contract EHS 70-110. The data to obtain this plot were taken from the final report for that contract titled "Exhaust Emissions from Gasoline-Powered Vehicles Above 6000 lb Gross Vehicle Weight" and dated April 1972. The data from each engine were normalized using the 3000 rpm, 100 percent power point as 1.00. Fuel rate at other conditions was obtained from the ratio of the fuel rate at the desired condition to the fuel rate at 3000 rpm, 100 percent power. The manifold vacuum and normalized fuel rate for the four engines was averaged for each of the constant speed data sets. The resultant plot of average normalized fuel rate versus average manifold vacuum is shown in Figure 34.

TABLE 89. SUMMARY OF NINE MODE WEIGHTING FACTORS CALCULATED FROM CAPE-21 DATA

	Modal Weighting Factor					
Data Base	Idle	C.T.	19"	16"	10"	3"
NY+LA (All)	0.250	0.292	0.085	0.112	0.096	0.165
NY+LA (SU)*	0.257	0.308	0.084	0.101	0.100	0.150
NY+LA(TT)**	0.208	0.205	0.082	0.180	0.066	0.259
LA (All)	0.143	0.278	0.085	0.141	0.121	0.232
LA (SU)	0.152	0.301	0.085	0.121	0.131	0.210
LA (TT)	0.107	0.166	0.077	0.233	0.082	0.336
NY (All)	0.329	0.330	0.089	0.085	0.072	0.095
NY (SU)	0.328	0.333	0.086	0.086	0.073	0.093
NY (TT)	0.334	0.314	0.102	0.086	0.041	0.123
Maximum	0.334	0.333	0.102	0.233	0.131	0.336
Minimum	0.107	0.166	0.082	0.085	0.041	0.093
Federal Register	0.232	0.143	0.057	0.308	0.147	0.113

---

* SU - Single Unit
** TT - Tractor Trailer

TABLE 90. COMPARISON OF 9-MODE BSFC AND LA-4 FUEL ECONOMY FOR SIX TRUCKS TESTED UNDER CONTRACT 68-01-0472

	9-mode Weighted BSFC			LA-4
Engine No.	1974 Weighting factors	CAPE-21 Weighting factors	% Diff.**	Normalized* mpg
2	0.726	0.722	-0.6	4.5
3-0	0.735	0.733	-0.3	5.3
4-0	0.794	0.818	+3.0	4.7
5-00	0.726	0.756	+4.1	5.3
6-0	0.916	0.875	-4.5	5.2
7-0	0.767	0.748	-2.5	5.0
	Avg. 0.782	Avg. 0.775		Avg. 5.0
	Coeff. of Var. 8.9%	Coeff. of Var. 7.6%		Coeff. of Var. 6.7%

---

* Normalized to 16,000 lbs vehicle test weight using .11 mpg/1000 lbs

** Percent difference between 1974 weighting factors and CAPE-21 weighting factors - 1974 is base value.

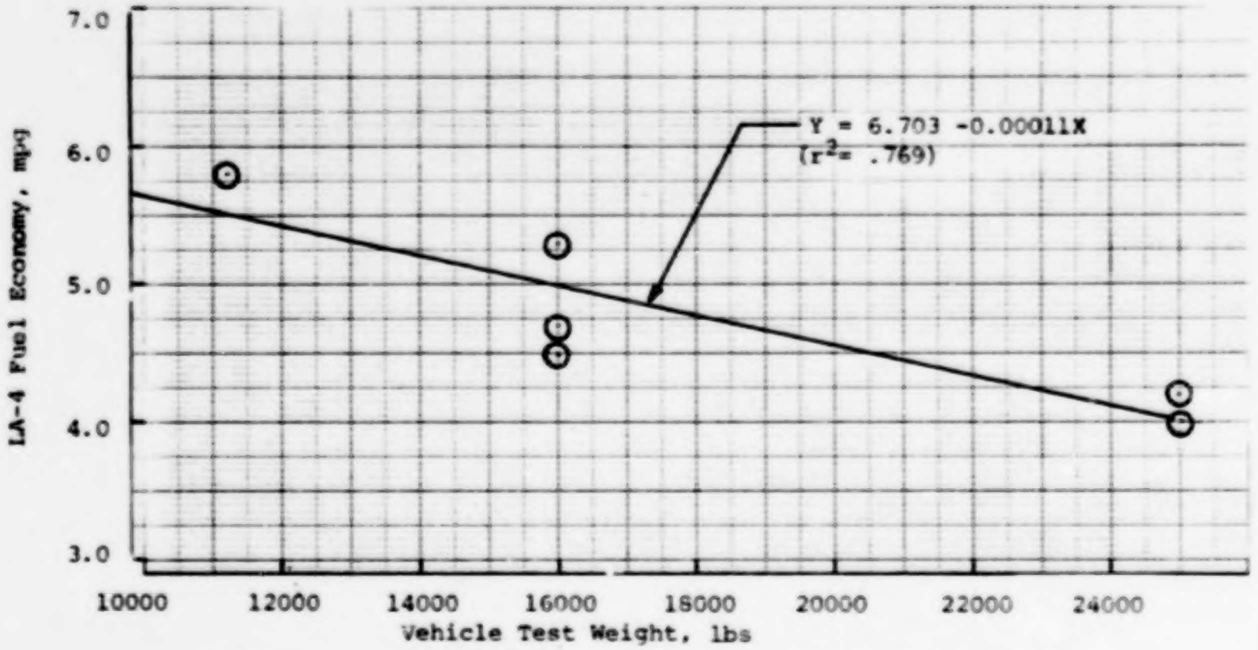


FIGURE 32. TEST WEIGHT VS. LA-4 FUEL ECONOMY FOR 6 TRUCKS TESTED UNDER CONTRACT 68-01-0472

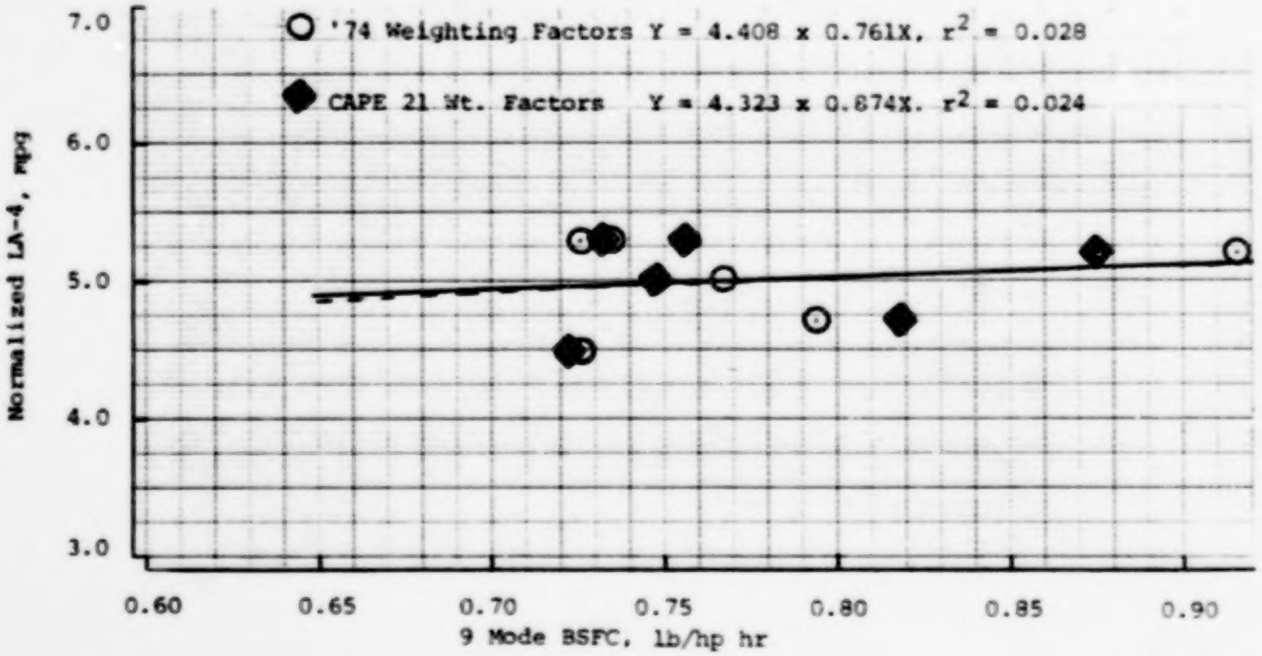


FIGURE 33. NINE-MODE BSFC VS. LA-4 FUEL ECONOMY FOR 6 TRUCKS TESTED UNDER CONTRACT 68-01-0472

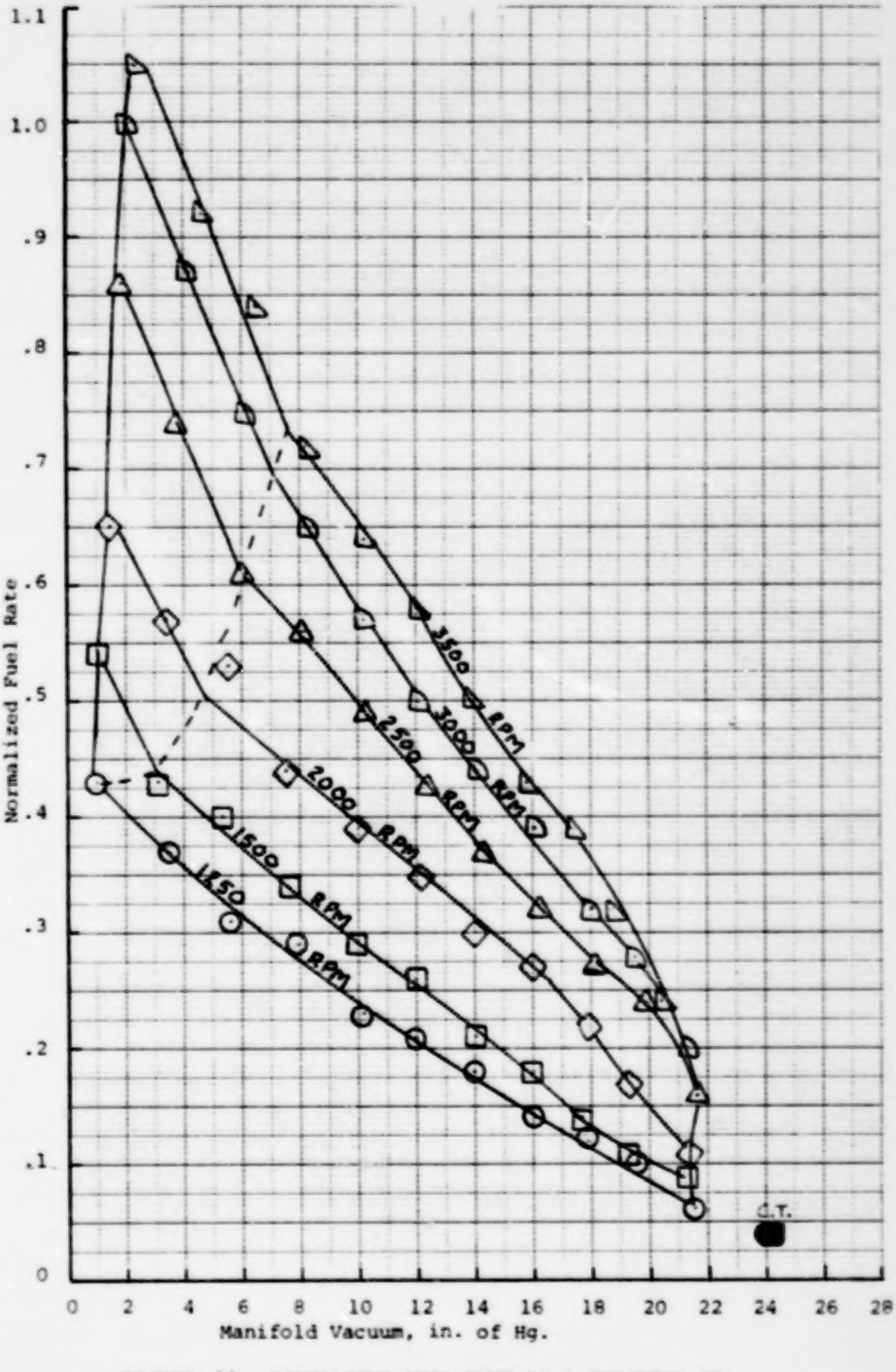


FIGURE 34. NORMALIZED FUEL RATE AS A FUNCTION OF MANIFOLD VACUUM AVERAGE OF 4 ENGINES

This data was then cross-plotted to give a curve of average normalized fuel rate versus rpm with lines of constant vacuum to facilitate obtaining a matrix showing fuel rate in an rpm-manifold vacuum matrix. A computer program was then written to multiply each element in this matrix by the corresponding element in the percent-time matrix from the CAPE-21 study to give a fuel consumed matrix. The program summed all the elements in this matrix, then calculated a percent of total fuel consumed for each element. The matrix showing percent of fuel consumed as a function of rpm and manifold vacuum is presented in Table 91. From this matrix, the percent of fuel consumed in each of the modes of the 9-mode test was calculated using the modal definitions previously established. The percent of fuel used in each mode is shown in Table 92. Note that the total percent fuel used that is covered by the 9-mode test is 47.1 percent.

The 9-mode weighting factors were then calculated as was previously done with the percent time matrix. That is, the calculated percent fuel consumed at idle was assumed to account for all of the idle fuel consumed, with the remaining percent fuel consumed in each mode equal to its fraction of the total time accounted for by the 9-mode test. The resulting 9-mode weighting factors are also shown in Table 92.

As was done with the weighting factors from the percent-time matrix, these weighting factors were used to calculate a new composite 9-mode BSFC for the six trucks from Contract 68-01-0472. These new values of composite BSFC are shown in Table 93 together with the 1974 weighting factors and the CAPE-21 percent time weighting factors. Also shown is the fuel economy for each truck from the LA-4 chassis dynamometer test. The fuel economy is plotted as a function of BSFC in Figure 35.

As can be seen from the figure, the percent fuel consumed method decreases the spread in the BSFC, but does not improve the correlation between the 9-mode BSFC and LA-4 fuel economy. Thus, it is not recommended that these weighting factors be used in any application where one truck would be compared to another truck.

It may be that there is not a single set of weighting factors that will correlate BSFC to on-the-road fuel economy. There are two things that can be done that may help to ascertain if this correlation is possible. The first, is to use the results of Item 2 of the Gasoline Truck Data Analysis in Section III of this report to see if a set of weighting factors can correlate the fuel consumption from the 9-mode test to the fuel consumption from transient chassis dynamometer tests. Another analysis that could be done is to check whether any set of weighting factors would correlate the composite 9-mode BSFC and the LA-4 fuel economy of the six trucks that have been used to check the usefulness of the CAPE-21 weighting factors. This could be done using the same linear programming technique developed for Item 2 of the Gasoline Truck Data Analysis Task.

The second of these approaches was tried first. It was planned to obtain new weighting factors that would best relate composite BSFC to the LA-4 fuel economy. However, because of constraints in the regression analysis program, it was necessary to use composite 9-mode fuel rate and LA-4 fuel rate in the analysis. The 9-mode fuel rate was normalized to

TABLE 91. AVERAGE ESTIMATED PERCENT FUEL USED IN GIVEN RPM-MANIFOLD VACUUM INTERVALS FOR ALL CAPE-21 TRUCKS (NEW YORK AND LOS ANGELES)

RPM/MV	0	1	2	3	4	5	6	7	8	9	10	11	12	13
200.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
600.	.01	.04	.03	.03	.03	.02	.02	.02	.01	.02	.02	.03	.03	.05
800.	.03	.11	.10	.08	.06	.06	.05	.05	.04	.04	.04	.05	.06	.06
1000.	.06	.16	.16	.12	.12	.10	.09	.09	.08	.08	.09	.09	.12	.16
1200.	.07	.23	.21	.19	.16	.14	.14	.12	.10	.10	.11	.12	.11	.16
1400.	.08	.24	.26	.25	.22	.18	.17	.16	.15	.14	.15	.13	.15	.16
1600.	.11	.41	.39	.40	.26	.22	.21	.19	.18	.17	.20	.17	.18	.20
1800.	.12	.50	.54	.37	.29	.25	.26	.23	.21	.19	.21	.21	.23	.23
2000.	.14	.56	.75	.44	.32	.26	.27	.28	.23	.22	.23	.24	.33	.31
2200.	.12	.64	.84	.60	.39	.32	.27	.27	.25	.24	.28	.26	.30	.27
2400.	.07	.78	1.41	1.00	.52	.40	.37	.39	.30	.33	.38	.36	.33	.31
2600.	.04	.67	2.17	1.65	.81	.61	.54	.48	.44	.45	.56	.52	.51	.43
2800.	0.00	.48	2.57	2.11	1.22	.87	.67	.55	.44	.50	.58	.53	.54	.47
3000.	0.00	.42	1.54	1.31	.86	.59	.40	.29	.27	.40	.33	.44	.35	.31
3200.	0.00	.17	.20	.55	.42	.19	.15	.19	.13	.12	.14	.13	.14	.17
3400.	0.00	.09	.28	.23	.25	.13	.09	.09	.05	.08	.07	.07	.06	.06
3600.	0.00	.04	.17	.12	.11	.10	.03	.03	.03	.03	.03	.05	.02	.02
3800.	0.00	0.00	.13	.12	.08	.07	.07	.03	.03	.03	.03	.02	.02	.02
4000.	0.00	0.00	.04	.08	.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4200.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4400.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

RPM/MV	14	15	16	17	18	19	20	21	22	23	24	25	26
200.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
600.	.14	.38	2.47	.86	1.41	1.26	.27	.09	0.00	0.00	0.00	0.00	0.00
800.	.07	.08	.20	.45	.66	.66	.40	.25	0.00	0.00	0.00	0.00	0.00
1000.	.26	.10	.10	.15	.20	.35	.57	.44	.08	0.00	0.00	0.00	0.00
1200.	.45	.16	.12	.12	.13	.15	.23	.14	.11	0.00	0.00	0.00	0.00
1400.	.21	.19	.18	.15	.13	.12	.14	.13	.10	.08	0.00	0.00	0.00
1600.	.23	.20	.19	.21	.15	.14	.14	.12	.08	.08	0.00	0.00	0.00
1800.	.26	.29	.23	.22	.21	.12	.11	.12	.05	.07	.06	0.00	0.00
2000.	.36	.36	.24	.25	.17	.17	.11	.12	.04	.05	.05	0.00	0.00
2200.	.29	.24	.34	.18	.14	.20	.11	.11	.03	.04	.04	.02	0.00
2400.	.32	.27	.23	.20	.14	.13	.11	.11	.03	.03	.03	.02	0.00
2600.	.41	.33	.29	.22	.15	.13	.12	.11	.02	.02	.02	.01	.00
2800.	.46	.37	.28	.29	.15	.12	.12	.09	.02	.02	.02	.01	.00
3000.	.31	.25	.19	.16	.10	.08	.07	.06	.01	.01	.01	.00	0.00
3200.	.19	.10	.08	.07	.05	.03	.03	.02	.01	.00	.00	.00	0.00
3400.	.06	.05	.03	.03	.03	.01	.01	.02	.00	.00	.00	.00	0.00
3600.	.02	.02	.02	.02	.01	.01	.01	.01	.00	0.00	0.00	.00	0.00
3800.	.02	.02	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00
4000.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4200.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4400.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 92. AVERAGE ESTIMATED PERCENT FUEL USED FOR THE SIX MANIFOLD VACUUM MODES OF THE NINE MODE FTP

Mode	Average-Estimated Percent Fuel Used in Mode	Weighting Factor From Percent Fuel Used
Idle (Mode 1)	13.64	0.136
16" (Modes 2, 4, 6, 8)	4.73	0.122 (total for 4 modes)
10" (Mode 3)	6.29	0.162
19" (Mode 5)	2.51	0.065
3" (Mode 7)	17.95	0.463
CT (Mode 9)	1.96	0.051
Total	47.08	

TABLE 93. COMPARISON OF 9-MODE BSFC AND LA-4 FUEL ECONOMY FOR SIX TRUCKS TESTED UNDER CONTRACT 68-01-0472

	9-Mode Weighted BSFC			
Engine Number	1974 Weighting Factors	CAPE-21 Weighting Factors % Time	% Fuel	LA-4 Normalized* mpg
2	0.726	0.722	0.596	4.5
3-0	0.735	0.733	0.588	5.3
4-0	0.794	0.818	0.598	4.7
5-00	0.726	0.756	0.625	5.2
6-0	0.916	0.875	0.612	5.1
7-0	0.767	0.748	0.589	4.8
Avg.	0.782	0.775	0.601	5.0
Coeff.of Var.	8.9%	7.6%	2.4%	6.7%

---

*Normalized to 16,000 lbs vehicle test weight using the inverse function, gallons/mile to obtain a better linear fit--factor is 0.0044 gallons per mile/1000 lbs GVW

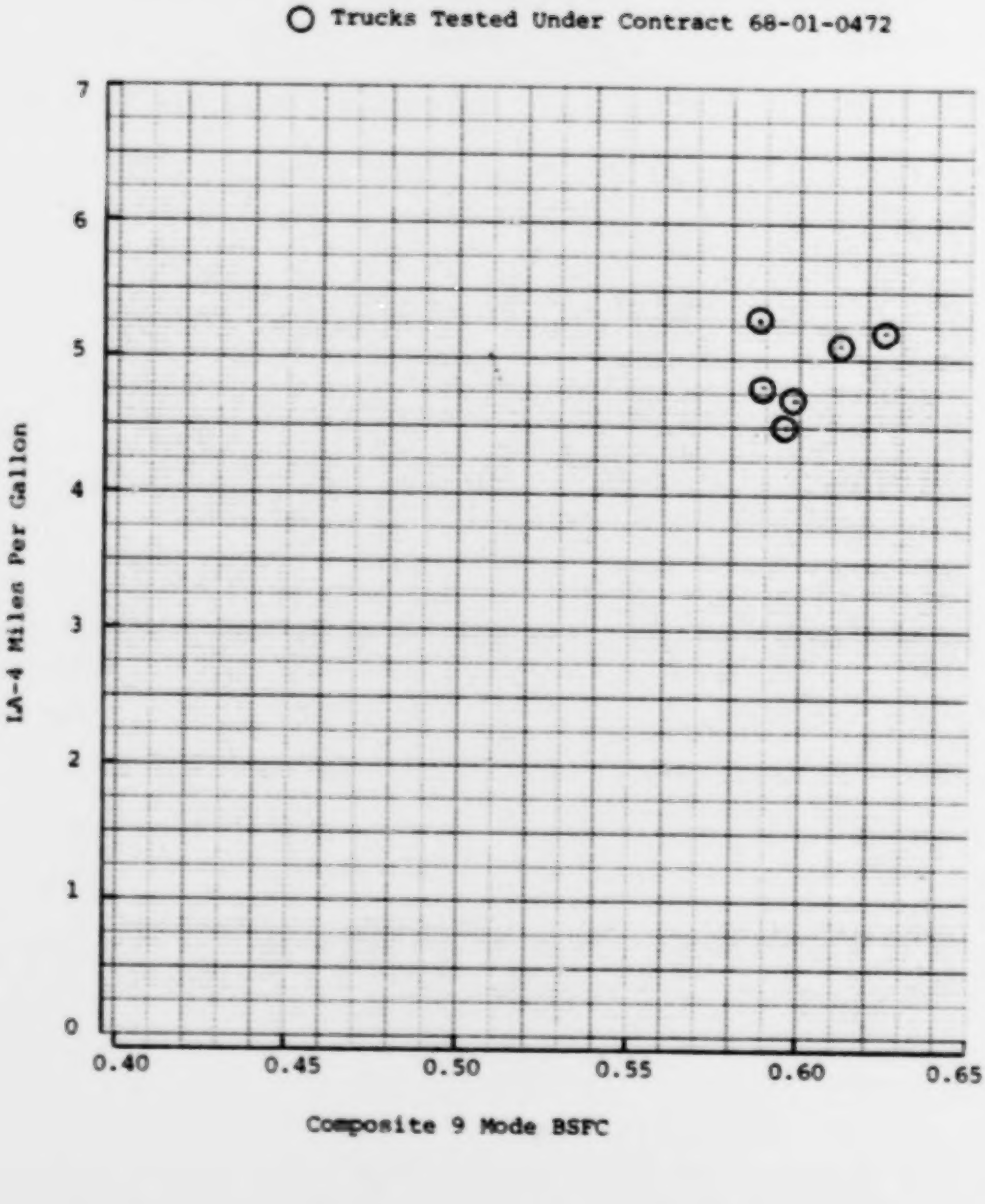


FIGURE 35. LA-4 MILES/GALLON AS A FUNCTION OF 9-MODE BSFC WITH WEIGHTING FACTORS FROM CAPE-21 PERCENT FUEL USED

400 CID since the modal fuel is a function of CID (see Item 2, Section III). The LA-4 fuel rate was normalized to 16,000 lbs vehicle test weight. Using these values, the new weighting factors were obtained.

The resulting composite 9-mode fuel rate and the LA-4 fuel rate were plotted and a linear regression line calculated. The plot and equation together with the correlation coefficient are shown in Figure 36. It is apparent that this relationship is not sufficiently linear to use as the basis of a comparison between the 9-mode test and on-the-road fuel economy. The approach was not pursued further since the other approach which was being done concurrently as part of Item 2, Section III showed greater possibilities of success.

This approach used data from Contract No. 68-03-2147 and involved reweighting the modal weighting factors to correlate the composite 9-mode results with the driving cycle results. As mentioned in the Gasoline Truck Data Analysis section of this report, the key factor in relating the 9-mode fuel rate and 20 mph driving cycle fuel rate was the determination of what vehicle test weight to use. It was found the fuel rate for each size engine varied with test weight in a non-linear fashion but that for each engine size, there was a point of zero slope at some test weight. The test weight at which this zero slope occurred was found to be a linear function of CID. The fuel rate at this zero slope point was also found to be a function of CID (see Figure 4, Section III).

It was felt that the data scatter around the linear relationship was perhaps caused by differences in engine thermal efficiency (i.e., BSFC). If this was so, then a method would be available to correlate 9-mode BSFC to road fuel economy since fuel rate in grams/min can be converted to mi/gal if the fuel density and average cycle speed are known. Using Figures 3 and 4 from Section III, a curve of fuel consumption normalized to an assumed constant BSFC (i.e., assuming all data fell on the regression line of Figure 4) versus vehicle test weight was developed for the nine single axle trucks tested under Contract 68-03-2147 (see Figure 37).

The LA-4 fuel rate for the six trucks from Contract 68-01-0472 was calculated at tested vehicle weight. Then, using Figure 37, the percent change in fuel rate from the test weight to vehicle weight at the point of zero slope of the fuel rate curve was calculated. This percent change was applied to the as-measured fuel rate of the six trucks to give the fuel rate at the "zero slope" vehicle weight. This fuel rate was then plotted as a function of engine CID (see Figure 38). As with the trucks from Contract 68-03-2147, the LA-4 fuel rate at these vehicle weights appears to be a strong function of CID.

If it can be shown that the percent variation of each point from some average line through the data is a function of the engine BSFC, the relationship will be complete. But which BSFC? There are four different composite 9-mode BSFC's that have been calculated for this set of data, each composite BSFC using different weighting factors. The percent difference between each data point and the straight line fit of the data was calculated and plotted as a function of each of the four sets of 9-mode composite BSFC's. The best relationship was with the "CAPE-21 percent-

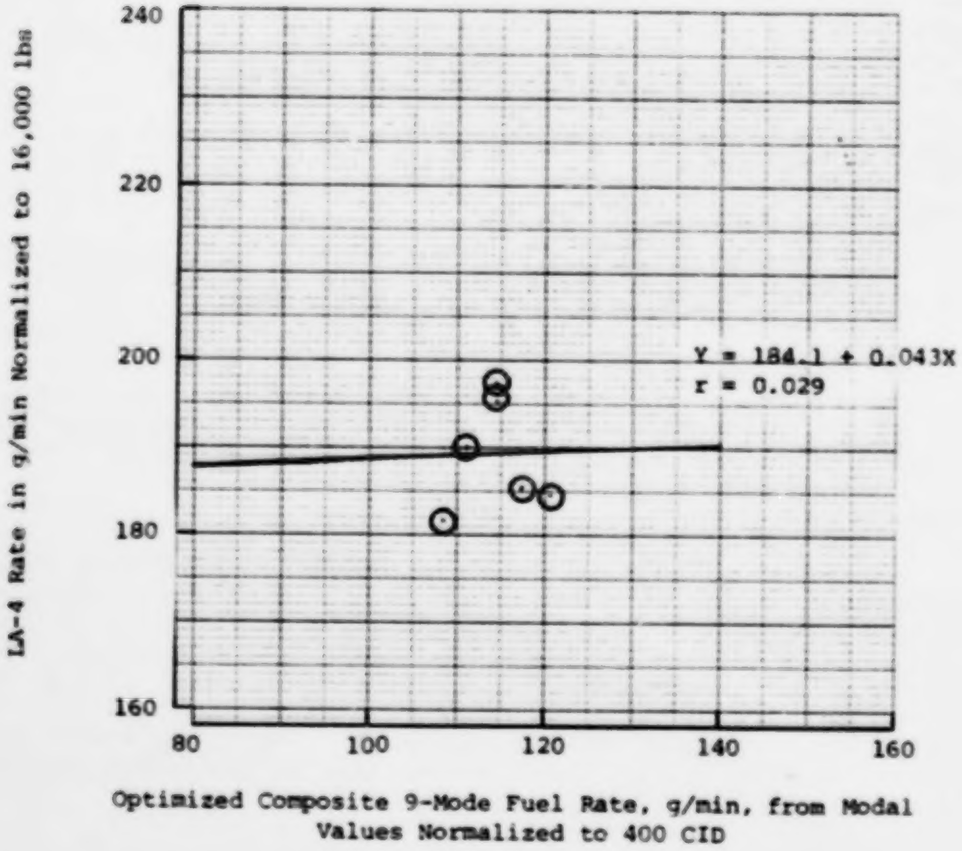


FIGURE 36. LA-4 FUEL RATE NORMALIZED TO 16,000 lb VS. OPTIMIZED 9-MODE FUEL RATE NORMALIZED TO 400 CID FOR 6 TRUCKS TESTED UNDER CONTRACT 68-01-0472

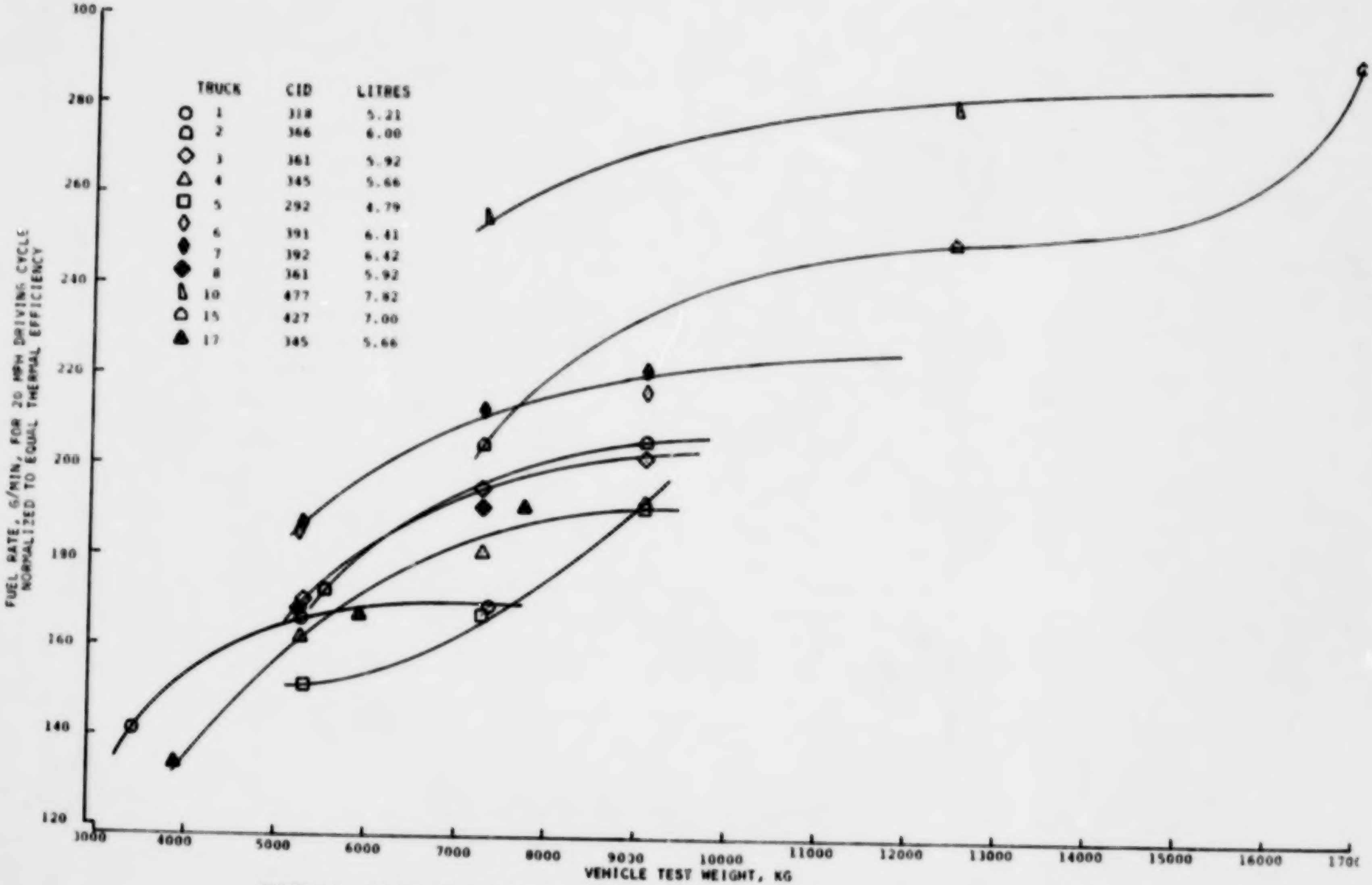


FIGURE 37. 20 MPH DRIVING CYCLE NORMALIZED FUEL RATE VERSUS VEHICLE WEIGHT FOR SEVERAL TRUCKS TESTED UNDER CONTRACT NO. 68-03-2147

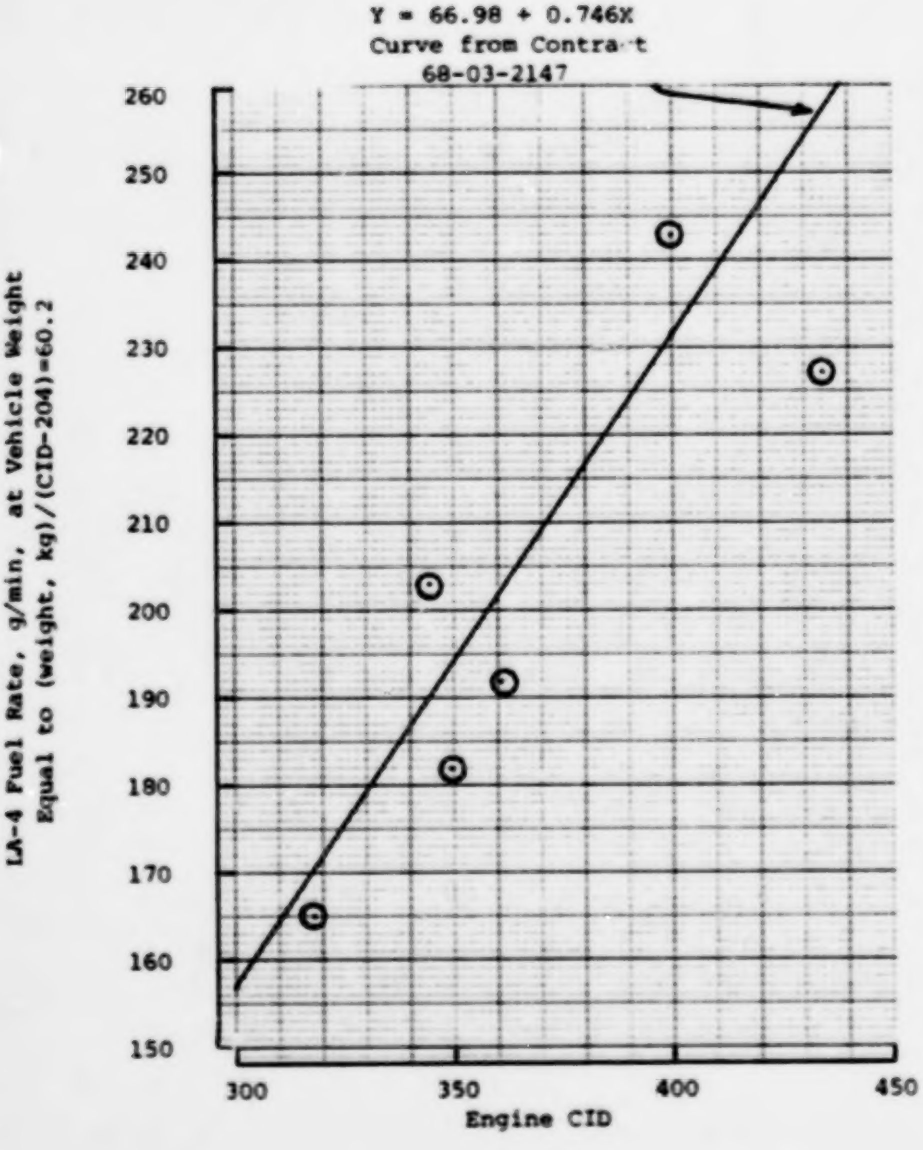


FIGURE 38. ENGINE CID VS. LA-4 FUEL RATE AT CERTAIN VEHICLE WEIGHTS FOR 6 TRUCKS TESTED UNDER CONTRACT 68-01-0472

time" weighting factors. Next, the CID versus LA-4 fuel rate linear relationship was changed slightly to a curvilinear relationship to improve the relationship of the 9-mode composite BSFC and the percent difference from the average line. The final relationship between BSFC and percent difference is shown in Figure 39. The final shape of the CID versus fuel rate curve is shown in Figure 40. Also shown are estimated lines of constant BSFC and the data points from the six trucks.

To summarize, a possible methodology for estimating fuel economy has been derived. As envisioned, the urban driving miles per gallon would be obtained for each engine at several vehicle weights (or even 1000 lb intervals) as follows.

First, the composite 9-mode BSFC is calculated using the CAPE-21 percent time weighting factors. Next, urban fuel economy is obtained from a curve similar to Figure 40 which would have urban fuel economy at the "zero slope" weight as a function of CID with lines of constant BSFC. Lastly, the fuel economy at other vehicle weights could be calculated using a curve similar to Figure 37. The curve would show nominal fuel economy as a function of vehicle weight for various engine CID values. The percent difference between the fuel economy at the desired weight and fuel economy at the "zero slope" weight would be calculated and the percent difference applied to the previously obtained fuel economy.

This method seemed sufficiently promising to pursue to this point. No further evaluation or improvement of this method was undertaken in this study because of its grossly empirical approach to fuel economy estimation and the large amount of vehicle testing required to make it work. For these reasons, it was deemed more cumbersome than desired for this project. However, this technique may merit additional EPA consideration in the future.

There remains one item in this task to be addressed. Only 53.1 percent of the CAPE-21 vehicle operating time was accounted for by the 9-mode procedure. This would normally not be judged as sufficient coverage. Part of the objective of this task was to define additional test modes, if necessary, so that the modal gasoline test adequately represents the average CAPE-21 truck operational pattern. Five additional modes were chosen from study of the CAPE-21 operational patterns. Four of these additional modes are listed in Table 94. The fifth mode was an additional closed throttle mode. Subsequent study has determined that fuel consumption varies little with speed at closed throttle so that one closed throttle mode could be used to represent all closed throttle operation.

The total area covered by the 9-mode test was presented previously representing 53.1 percent of the operating time. The four new modes, plus extension of the CT mode to include all closed throttle operation gives a new total operating time covered of 75.7 percent. The percent time represented by each mode is shown in Table 94. Of course, more or less time could be used for the total time represented, if the area of each mode represented were changed. It is obvious, however, that the four new modes are in the areas of relatively high percent operating time.

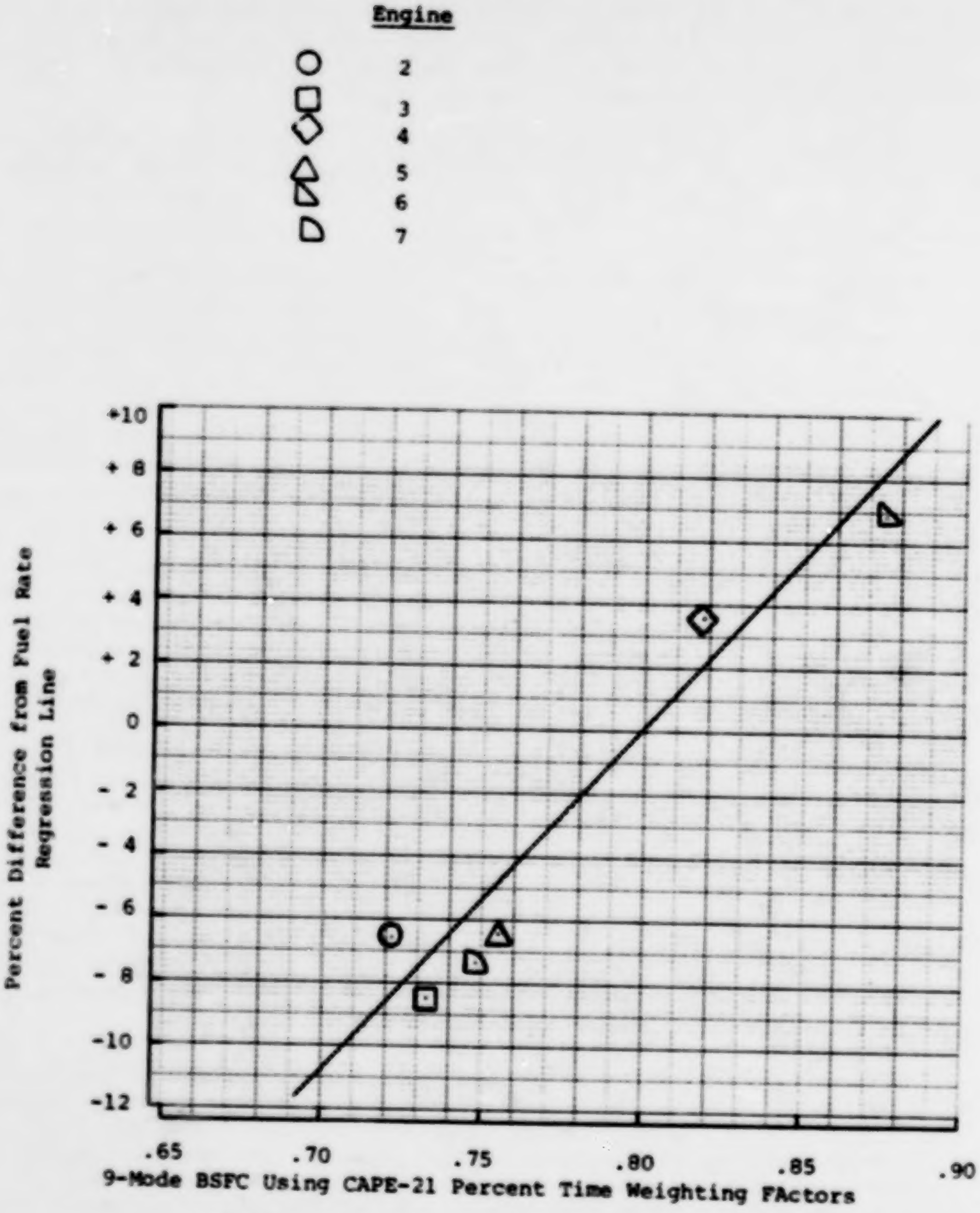


FIGURE 39. PERCENT DIFFERENCE FROM FUEL RATE REGRESSION LINE VS. 9-MODE BSFC FOR 6 TRUCKS FROM CONTRACT 68-01-0472

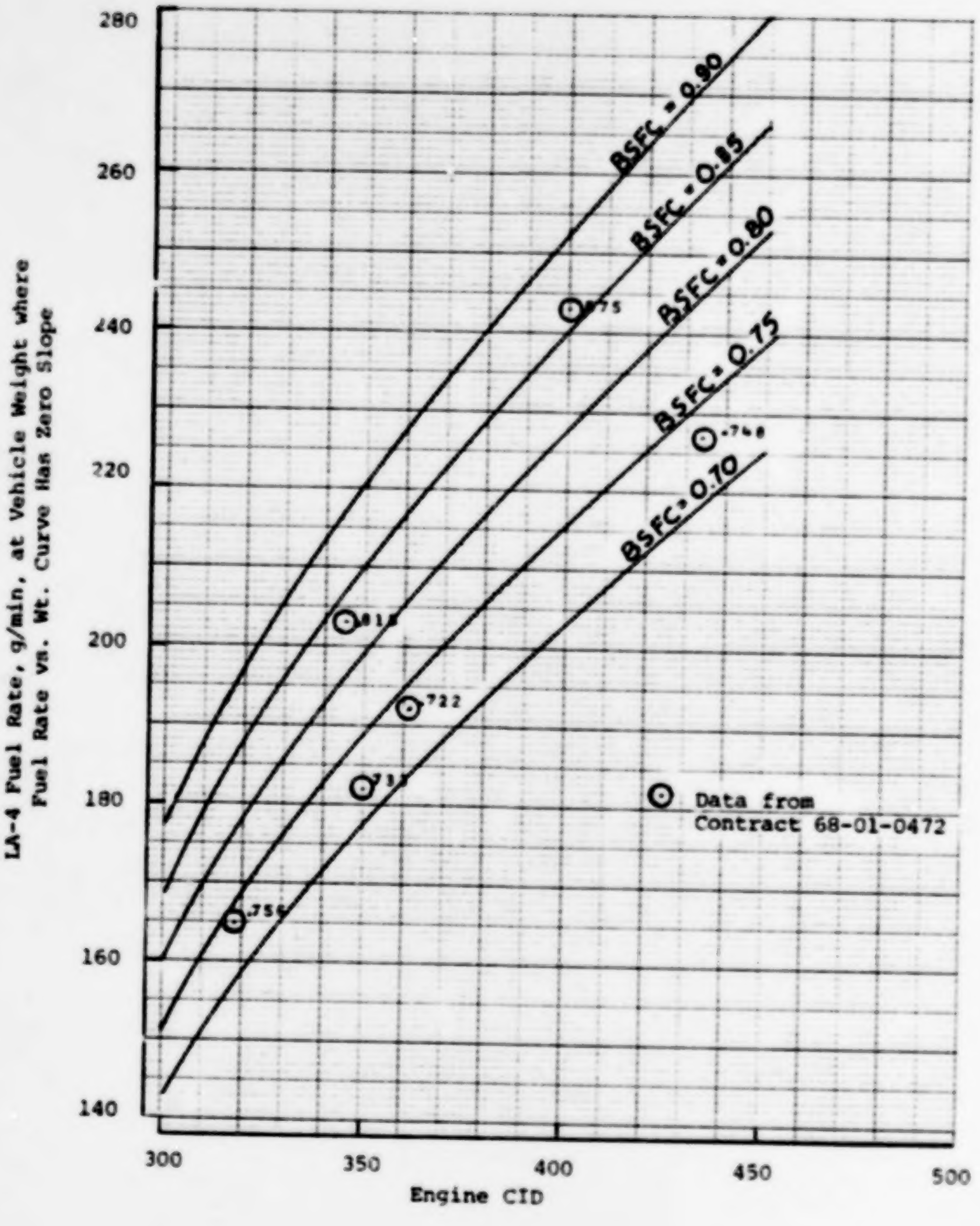


FIGURE 40. ENGINE CID VS. LA-4 FUEL RATE
AT CERTAIN VEHICLE WEIGHTS

TABLE 94. PERCENT OF CAPE-21 TRUCK OPERATING TIME REPRESENTED BY VARIOUS ENGINE SPEED AND MANIFOLD VACUUM MODES (ALL TRUCKS FROM NEW YORK AND LOS ANGELES)

		Percent Time
I.	Modes of 9-Mode FTP	
	3" Hg. vacuum, 2000 rpm	6.20
	10" Hg. vacuum, 2000 rpm	3.59
	16" Hg. vacuum, 2000 rpm	4.22
	19" Hg. vacuum, 2000 rpm	3.15
	C. T. 2000 rpm	11.03
	Idle	24.96
	Total 9-Mode FTP	53.15
II.	Suggested Additional Modes	
	6" Hg. vacuum, 2700 rpm	3.25
	13" Hg. vacuum, 2700 rpm	4.36
	14" Hg. vacuum, 1100 rpm	4.04
	19" Hg. vacuum, 1100 rpm	7.05
	Total Additional Modes	18.70
III.	Additional C.T.	3.84
IV.	Total Percent Time	75.69

While this study did not produce a simple set of weighting factors that would relate 9-mode BSFC to on-the-road fuel economy, it did investigate the various methods that appeared promising and did show that there is no simple relationship between 9-mode BSFC and vehicle fuel economy.

VI. DIESEL WEIGHTING FACTOR DEVELOPMENT

This section covers the analysis done in an attempt to develop a set of weighting factors that could be applied to the 13-mode FTP test for heavy-duty diesel-powered trucks which would relate the 13-mode brake specific fuel consumption (BSFC) to on-the-road fuel economy. Additional modes were to be considered if necessary.

Data Base

The data from the CRC CAPE-21 study was the primary data used in this analysis. There were 14 diesel-powered trucks tested in New York City and 17 in Los Angeles. A description of the trucks is included in Appendix A. The CAPE-21 data used was in the form of a matrix for each truck showing percent time spent in a set of percent rpm and percent power intervals. The percent power was calculated from rail pressure, rack position, or throttle position depending on the truck. The conversion model was developed by EPA from manufacturers data.(23)

Approach

The basic appraoch was to attempt to develop weighting factors utilizing the present 13-mode test as much as possible, but also considering the addition of other modes that could be added to the present procedures with no change in test equipment and reasonable increases in test time. The first step would be to obtain the CAPE-21 percent time matrices for each truck, together with descriptions of the trucks.

Once the matrices were assembled, they would be divided by truck into groups by body style. The first question to be answered would be: Can the current 13-mode procedure be used "as is" for a fuel consumption test, with possibly some reweighting of the modes? In other words, do the trucks operate enough of the time in the range covered by the 13-mode procedure? It should be kept in mind that the 13-mode procedure really has ten different modes plus idle. To determine if this is so, the percent time spent at the 13-mode speed and power modes would be calculated for each truck along with the group average, maximum, minimum, range, standard deviation and coefficient of variation. Whether the 13-mode schedule can be used or not, weighting factors would be calculated from percent time in mode. If the average percentage time spent in these modes and the range and coefficient of variation are acceptable, then the present 13-mode schedule could be used with the calculated weighting factors. If the new weighting factors are close enough to the present weighting factors, consideration would be given to using the present factors.

It could be entirely possible that the current 13-modes would not cover a sufficient amount of the truck's operating time. If this is so, then other modes would be considered. The initial method of choosing the modes would be to try and add additional power modes at either of the two rpm levels of the 13-mode test. If this did not yield sufficient average operating time and acceptable coefficients of variation, then additional power modes at a single additional speed would be tried.

The assumption implicit in the above procedure is that if the BSFC from the various modes is weighted by the percent of time that mode is actually encountered on the road, then there will be a correlation between test BSFC and on-the-road fuel economy. It was recognized that some means of correlating the weighting factors resulting from this study with actual truck operation is needed. It is important to show that if an engine has a lower composite BSFC than another engine on the test stand, it will have a lower fuel consumption in actual transient operation in a truck. It was decided to use the data from EPA Contract 68-03-2147 to attempt this correlation.

Analysis

The first item of analysis was to obtain average percent-time matrices for all the CAPE-21 trucks and various sub-sets of the trucks. Table 95 shows the average percent-time matrix for all of the CAPE-21 diesel trucks. The percent power and percent rpm values shown are for the midpoint of the interval. The column headed "motor" gives the percent time that the engine was motoring at each percent rpm. Engine idle is the zero percent rpm, zero percent power cell. The column headed "row total" gives the total percent time spent in each percent rpm regardless of power. The column headed "col sum" gives the percent time spent in each percent power regardless of rpm. Tables 96, 97, and 98 contain the average percent time matrices for all Los Angeles trucks, Los Angeles single unit trucks, and Los Angeles tractor trailers, respectively. Tables 99, 100 and 101 contain the same information for the New York City trucks. Examining the two matrices containing the average percent time for all trucks in each city, it can be seen that the Los Angeles all-truck matrix shows a different pattern of operation than the New York all-truck matrix.

As an aid to visualizing the operational patterns from the two cities, Figures 41 and 42 show the Los Angeles and New York all-truck matrices with the percent operating time divided into intervals and shaded to enhance the distinction between intervals. Figure 43 shows the matrix with various regions of engine operation indicated on the matrix. Comparing Figures 41 and 42, it can be seen that the Los Angeles matrix shows a large amount of time at high engine speed and moderate to high power; while the New York matrix shows a much smaller amount of time at these operating conditions. The New York matrix shows more operating time at low speed, low power conditions than the Los Angeles matrix. The trucks in New York also apparently operated over a wider power range at low speeds than did the Los Angeles trucks. These distinctly different operating patterns for the two cities make the development of 13-mode weighting factors for fuel consumption that would be applicable nationwide more difficult.

Since there is a difference in the operating patterns for New York and Los Angeles, the calculations for the 13-mode weighting factors were done for each city individually as well as for the combined data from both cities. However, before calculating the weighting factors, one of the basic questions to be resolved was just how large an rpm-power area should each mode be assumed to represent. At the extreme, the whole matrix (less the motoring column) could be divided up among the 11 different modes of the 13-mode test. However, as explained in the analysis of the CAPE-21 data for gasoline-powered trucks, the relationship between fuel rate and rpm and fuel rate and power can vary from engine to engine. Thus, when comparing engines, an engine with a lower fuel rate at one rpm and power condition may not necessarily have a lower fuel rate at another rpm and power condition. This would indicate that it is not prudent to let the fuel rate

TABLE 95. PERCENT TIME IN PERCENT POWER AND PERCENT ENGINE SPEED INTERVALS FOR ALL DIESEL TRUCKS TESTED IN CAPE-21 STUDY

PCT RPM	PERCENT POWER MOTOR	0	10	20	30	40	50	60	70	80	90	100	ROW TOTAL
-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-10	.00	0.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.03
0	1.15	28.25	1.06	1.06	.33	.26	.27	.14	.04	.07	.04	.08	32.73
10	.70	.12	.23	.21	.19	.10	.07	.05	.06	.09	.03	.00	1.81
20	.93	.09	.22	.21	.19	.10	.09	.08	.09	.10	.04	.00	2.09
30	1.15	.12	.27	.19	.19	.13	.13	.11	.12	.15	.08	.01	2.59
40	1.35	.15	.26	.23	.19	.18	.15	.15	.17	.20	.18	.03	3.25
50	1.62	.16	.25	.22	.29	.20	.16	.17	.20	.29	.28	.05	3.79
60	2.15	.15	.32	.29	.28	.27	.19	.18	.19	.25	.39	.10	4.70
70	2.75	.25	.51	.50	.59	.50	.93	.36	.39	.39	.65	.27	7.98
80	3.16	.38	.78	.89	.99	1.11	1.11	1.08	1.02	1.06	1.59	.82	13.99
90	2.66	.36	.62	.75	.96	1.08	1.17	1.16	1.16	1.21	1.68	.96	13.78
100	2.05	.28	.52	.58	.66	.69	.69	.69	.60	.57	.76	.79	8.85
110	.45	.05	.05	.06	.08	.10	.11	.19	.18	.22	.25	.20	1.90
120	.10	.00	.01	.01	.00	.01	.01	.01	.01	.02	.03	.04	.25
130	.00	0.00	0.00	0.00	0.00	.00	0.00	.00	0.00	0.00	0.00	.00	.01
140	.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00
COL SUM	20.22	30.37	5.11	5.15	4.79	4.69	4.58	4.28	4.23	4.50	6.01	3.31	

NOTE: Areas marked are taken to represent the modal operating conditions from the diesel 13-mode test.

TABLE 96. PERCENT TIME IN PERCENT POWER AND PERCENT ENGINE SPEED INTERVALS FOR ALL LOS ANGELES DIESEL TRUCKS TESTED IN CAPE-21 STUDY

PCT	PERCENT POWER												ROW
RPM	MOTOR	0	10	20	30	40	50	60	70	80	90	100	TOTAL
-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-10	.00	0.00	.00	0.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
0	.46	17.07	.30	.56	.20	.13	.14	.09	.07	.05	.03	.01	19.10
10	.58	.07	.13	.08	.04	.02	.01	.00	.01	.01	.01	.00	.98
20	.78	.06	.11	.06	.04	.02	.02	.01	.01	.01	.01	.00	1.10
30	.99	.07	.10	.07	.04	.02	.02	.01	.01	.02	.02	.01	1.36
40	1.25	.06	.11	.09	.06	.05	.03	.02	.02	.02	.03	.01	1.76
50	1.67	.08	.15	.12	.10	.07	.05	.04	.05	.03	.04	.01	3.41
60	2.48	.14	.27	.26	.23	.17	.12	.11	.08	.09	.10	.03	4.09
70	3.53	.34	.63	.70	.73	.67	.55	.43	.38	.39	.53	.33	9.20
80	4.42	.54	1.19	1.33	1.58	1.78	1.77	1.76	1.65	1.58	2.17	1.30	21.08
90	3.79	.45	1.01	1.22	1.55	1.78	1.91	1.88	1.86	1.77	2.20	1.31	20.72
100	3.13	.39	.88	.96	1.07	1.11	1.08	.97	.88	.78	.91	.69	12.85
110	.51	.04	.07	.09	.10	.12	.14	.17	.21	.25	.29	.25	2.25
120	.09	.00	.01	.01	.00	.01	.00	.01	.01	.01	.02	.02	.18
130	.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00
140	.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00
	23.69	19.30	4.96	5.54	5.73	5.95	5.82	5.51	5.24	5.02	6.35	3.98	

TABLE 97. PERCENT TIME IN PERCENT POWER AND PERCENT ENGINE SPEED INTERVALS
FOR LOS ANGELES SINGLE UNIT DIESEL TRUCKS TESTED IN CAPE-21 STUDY

PCT RPM	PERCENT POWER												ROW TOTAL
	MOTOR	0	10	20	30	40	50	60	70	80	90	100	
-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-10	0.00	0.00	.00	0.00	0.00	.00	.00	.01	.01	.01	.01	.00	.05
0	.38	20.58	.20	.22	.17	.13	.21	.13	.09	.06	.05	.02	22.24
10	.37	.11	.24	.14	.08	.04	.02	.01	.01	.01	.03	.01	1.05
20	.58	.11	.21	.10	.06	.03	.02	.01	.02	.01	.02	.01	1.17
30	.82	.13	.15	.11	.06	.03	.02	.02	.01	.02	.03	.01	1.41
40	1.05	.10	.19	.13	.08	.07	.04	.03	.02	.03	.05	.01	1.81
50	1.30	.11	.20	.13	.13	.07	.06	.04	.03	.03	.07	.03	2.22
60	2.01	.16	.26	.25	.23	.15	.12	.09	.06	.07	.11	.06	3.59
70	2.54	.33	.52	.53	.55	.51	.41	.34	.26	.30	.66	.49	7.44
80	3.53	.52	.95	1.09	1.40	1.64	1.72	1.77	1.58	1.19	2.36	1.79	19.56
90	3.12	.46	1.05	1.48	1.97	2.17	2.46	2.61	2.40	2.09	2.94	2.19	24.88
100	1.31	.17	.50	.72	.89	1.07	1.05	.97	.85	.83	.83	.85	10.04
110	.20	.04	.06	.08	.10	.13	.12	.13	.21	.25	.21	.20	1.74
120	.00	0.00	.01	.01	0.00	.00	.00	.01	.01	.01	.01	.01	.07
130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
COL SUM	17.21	22.83	4.54	4.98	5.73	6.04	6.27	6.18	5.55	4.90	7.39	5.69	

TABLE 98. PERCENT TIME IN PERCENT POWER AND PERCENT ENGINE SPEED INTERVALS
FOR LOS ANGELES TRACTOR TRAILER DIESEL TRUCKS TESTED IN CAPE-21 STUDY

PCT	PERCENT POWER												ROW
RPM	MOTOR	0	10	20	30	40	50	60	70	80	90	100	TOTAL
-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-10	.00	0.00	0.00	0.00	.00	.00	0.00	0.00	0.00	.00	.00	0.00	.00
0	.50	15.16	.35	.75	.21	.14	.09	.06	.05	.04	.02	.00	17.38
10	.70	.05	.07	.05	.02	.01	.00	.00	.01	.01	.01	0.00	.94
20	.88	.03	.05	.03	.02	.01	.01	.01	.01	.01	.01	0.00	1.06
30	1.08	.03	.07	.04	.02	.02	.01	.01	.01	.01	.01	.00	1.32
40	1.36	.04	.08	.06	.05	.03	.02	.02	.02	.02	.01	.00	1.73
50	1.87	.06	.12	.11	.08	.08	.04	.04	.06	.04	.02	.00	2.52
60	2.74	.13	.28	.27	.22	.18	.12	.12	.09	.10	.09	.02	4.36
70	4.07	.34	.69	.79	.82	.76	.62	.48	.45	.43	.46	.24	10.16
80	4.91	.55	1.32	1.46	1.68	1.86	1.80	1.75	1.69	1.79	2.06	1.04	21.92
90	4.16	.45	.99	1.08	1.32	1.56	1.61	1.48	1.56	1.60	1.80	.86	18.45
100	4.12	.50	1.04	1.09	1.16	1.13	1.09	.97	.90	.76	.95	.61	14.34
110	.68	.03	.08	.09	.10	.11	.14	.19	.21	.25	.33	.28	2.52
120	.14	.00	.01	.01	.01	.01	.01	.01	.01	.02	.02	.02	.25
130	.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00
140	.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00
COL													
SUM	27.22	17.38	5.14	5.84	5.74	5.91	5.58	5.14	5.08	5.08	5.78	3.08	

TABLE 99. PERCENT TIME IN PERCENT POWER AND PERCENT ENGINE SPEED INTERVALS FOR ALL NEW YORK DIESEL TRUCKS TESTED IN CAPE-21 STUDY

PCT RPM	PERCENT POWER												ROW TOTAL
	MOTOR	0	10	20	30	40	50	60	70	80	90	100	
-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-10	.00	0.00	0.00	.00	.02	0.00	.00	.00	0.00	.00	0.00	0.00	.03
0	1.99	41.82	1.98	1.66	.49	.40	.42	.21	.13	.09	.06	.03	49.29
10	.85	.17	.35	.37	.37	.19	.15	.11	.12	.08	.04	.00	2.82
20	1.12	.14	.37	.39	.26	.19	.19	.16	.18	.20	.08	.01	3.29
30	1.34	.18	.48	.34	.27	.26	.27	.22	.24	.30	.16	.02	4.08
40	1.46	.26	.45	.40	.34	.35	.30	.31	.35	.41	.37	.06	5.06
50	1.55	.27	.37	.36	.40	.35	.30	.33	.38	.48	.57	.10	5.46
60	1.74	.17	.37	.30	.34	.31	.28	.26	.33	.44	.74	.18	5.45
70	1.80	.14	.37	.26	.30	.29	.29	.28	.28	.39	.80	.19	5.39
80	1.63	.20	.27	.24	.28	.30	.30	.26	.25	.42	.88	.23	5.26
90	1.24	.25	.15	.18	.24	.29	.27	.24	.31	.53	1.06	.59	5.34
100	.79	.15	.08	.11	.16	.14	.23	.24	.26	.31	.58	.91	3.98
110	.37	.06	.03	.03	.05	.07	.08	.11	.19	.18	.21	.19	1.57
120	.11	.00	.01	.01	.01	.01	.01	.01	.02	.03	.04	.06	.32
130	.01	0.00	0.00	0.00	0.00	.00	0.00	.00	0.00	0.00	0.00	.01	.02
140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
COL SUM	16.00	43.81	5.28	4.67	3.53	3.16	3.08	2.74	3.00	3.87	5.59	2.49	

TABLE 100. PERCENT TIME IN PERCENT POWER AND PERCENT ENGINE SPEED INTERVALS
FOR NEW YORK SINGLE UNIT DIESEL TRUCKS TESTED IN CAPE-21 STUDY

PCT RPM	PERCENT POWER												ROW TOTAL
	MOTOR	0	10	20	30	40	50	60	70	80	90	100	
-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-10	.00	0.00	0.00	0.00	0.00	0.00	.00	.01	0.00	0.00	0.00	0.00	.01
0	1.81	46.32	.48	.41	.50	.36	.62	.28	.15	.12	.09	.03	51.17
10	.61	.14	.22	.43	.59	.21	.16	.12	.10	.12	.08	.01	2.79
20	.81	.07	.35	.55	.28	.24	.24	.18	.20	.23	.11	.01	3.28
30	.86	.08	.60	.30	.24	.29	.33	.24	.33	.41	.09	.01	3.77
40	.93	.30	.46	.29	.27	.32	.31	.38	.54	.58	.33	.08	4.79
50	1.22	.35	.31	.30	.32	.28	.31	.38	.58	.71	.63	.07	5.48
60	1.39	.19	.33	.35	.36	.31	.29	.29	.46	.69	.93	.20	5.79
70	1.35	.12	.28	.39	.36	.32	.30	.31	.33	.43	.87	.33	5.39
80	1.12	.08	.23	.31	.33	.37	.36	.31	.28	.30	.63	.36	4.69
90	.85	.06	.21	.28	.33	.29	.31	.34	.41	.47	.81	.35	4.71
100	.54	.03	.11	.18	.26	.26	.26	.24	.23	.27	.39	.19	2.88
110	.33	.01	.09	.06	.09	.14	.15	.19	.22	.23	.21	.17	1.86
120	.07	.01	.02	.02	.01	.02	.02	.03	.04	.07	.08	.13	.52
130	0.00	0.00	0.00	0.00	0.00	.01	0.00	.00	0.00	0.00	0.00	.01	.02
140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
COL SUM	11.89	47.75	3.69	3.82	3.97	3.41	3.68	3.31	3.88	4.50	5.22	1.85	

TABLE 101. PERCENT TIME IN PERCENT POWER AND PERCENT ENGINE SPEED INTERVALS FOR NEW YORK TRACTOR TRAILER DIESEL TRUCKS TESTED IN CAPE-21 STUDY

PCT	PERCENT POWER												ROW
RPM	MOTOR	0	10	20	30	40	50	60	70	80	90	100	TOTAL
-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-10	0.00	0.00	0.00	.00	.04	0.00	.00	0.00	0.00	.00	0.00	0.00	.04
0	2.12	38.44	3.11	2.59	.48	.44	.28	.16	.11	.07	.04	.04	47.88
10	1.09	.20	.45	.33	.21	.18	.13	.10	.13	.06	.01	0.00	2.89
20	1.36	.19	.37	.28	.24	.16	.19	.19	.17	.18	.05	.01	3.30
30	1.59	.25	.39	.37	.29	.29	.22	.20	.18	.23	.21	.09	4.31
40	1.85	.24	.49	.48	.40	.38	.28	.26	.21	.28	.40	.04	5.31
50	1.80	.20	.42	.40	.46	.39	.30	.29	.23	.31	.51	.12	5.44
60	2.00	.15	.41	.26	.32	.31	.27	.21	.23	.20	.60	.16	5.23
70	2.13	.16	.43	.21	.26	.27	.28	.25	.24	.36	.75	.09	5.43
80	2.01	.28	.31	.19	.24	.24	.26	.22	.23	.52	1.07	.13	5.70
90	1.62	.39	.10	.11	.17	.20	.24	.25	.23	.50	1.29	.68	5.81
100	.84	.25	.06	.07	.09	.19	.20	.24	.28	.39	.76	1.44	4.80
110	.40	.04	.02	.01	.01	.02	.03	.05	.08	.19	.21	.11	1.18
120	.15	.00	.00	.00	.00	.00	0.00	0.00	.00	.00	.00	.01	.17
130	.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.02
140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
COL SUM	19.08	40.85	6.51	5.31	3.20	2.97	2.63	2.39	2.33	3.34	5.87	2.97	

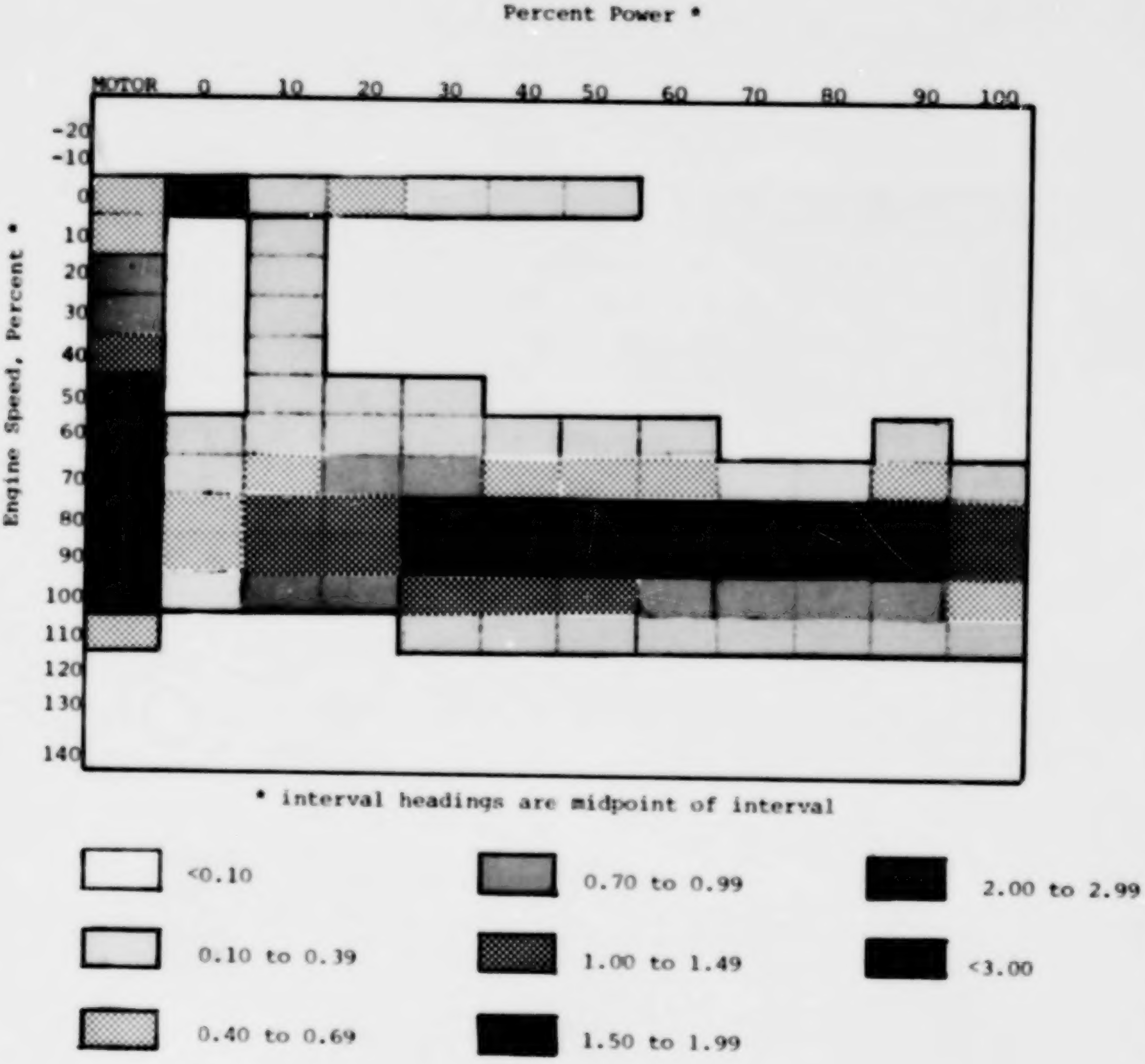
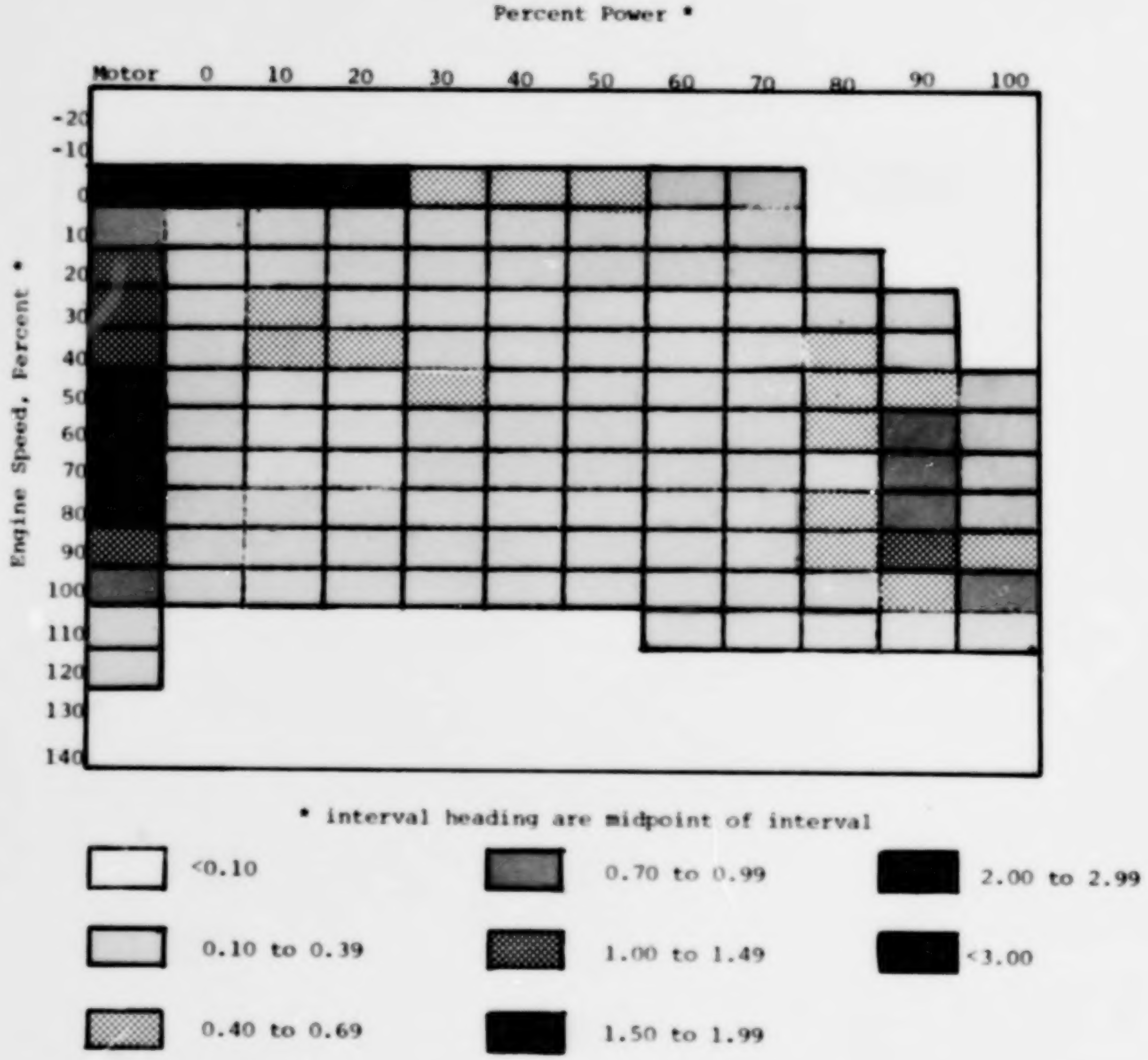
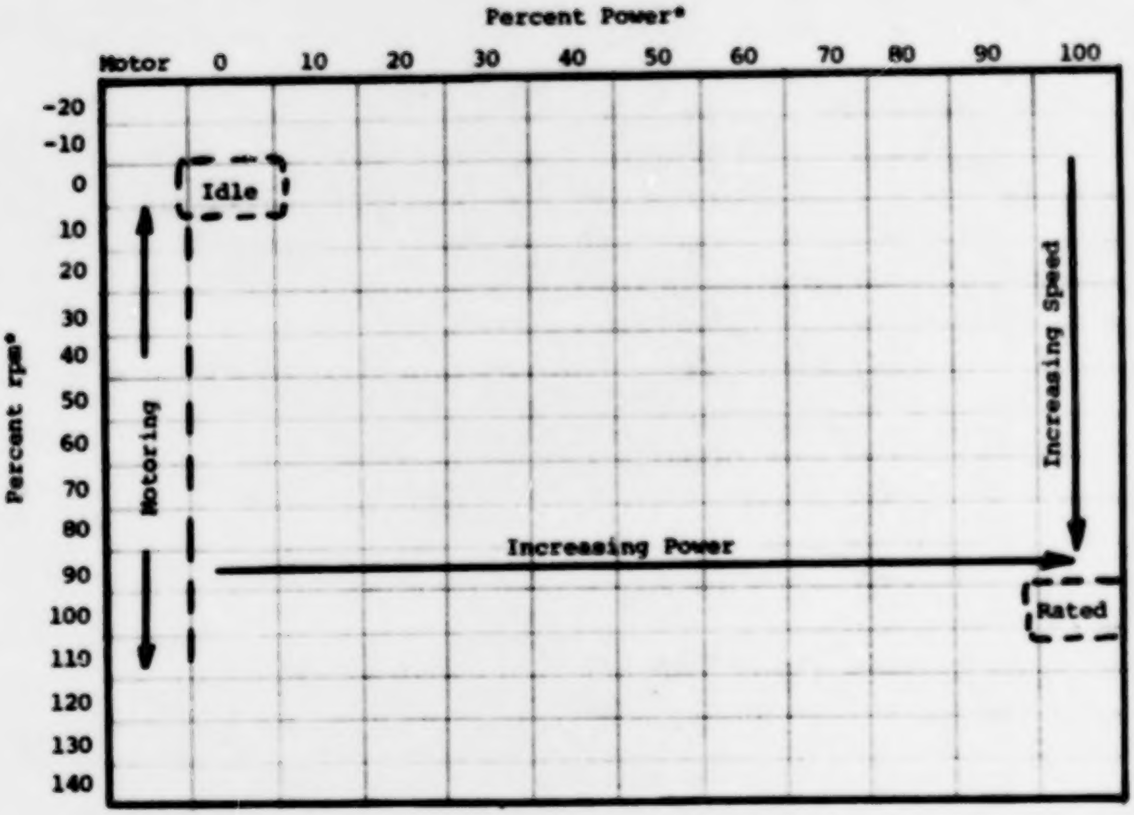


FIGURE 41. AVERAGE TIME SPENT IN VARIOUS PERCENT ENGINE SPEEDS AND PERCENT POWER FOR ALL 17 DIESEL TRUCKS IN THE LOS ANGELES CAPE-21 STUDY



* interval heading are midpoint of interval

FIGURE 42. AVERAGE TIME SPENT IN VARIOUS PERCENT ENGINE SPEEDS AND PERCENT POWER FOR ALL 14 DIESEL TRUCKS IN THE NEW YORK CAPE-21 STUDY



* Invertal heading are mid-point of interval

FIGURE 43. DIESEL TRUCK PERCENT POWER-PERCENT SPEED MATRIX SHOWING ENGINE OPERATING AREAS

at each mode be represented by a large area of the matrix. With this in mind and in an attempt to be compatible with the gasoline truck analysis in Section V of this report, the matrix cells represented by each of the modes of the 13-mode test were chosen as the intervals outlined in Table 95.

The idle mode was represented by the matrix cell labeled zero percent speed and zero percent power. The engine speed intervals labeled 90, 100, and 110 percent speed were chosen to represent the rated speed modes. The engine speed intervals labeled 50, 60, and 70 percent speed were chosen to represent the intermediate speed modes. Within each speed, the two percent power mode was represented by the zero percent power cell; the 25 percent power mode by the 20 and 30 percent power cells; the 50 percent power mode by the 50 percent power cell; the 75 percent power mode by the 70 and 80 percent power cells; and the 100 percent power mode by the 100 percent power cell.

The percent-time matrices from each truck were processed using a computer program written to choose the 13-mode conditions from the matrix for each truck and determine the average, minimum, and maximum time spent in each mode for the group of trucks processed. The resulting computer printouts showing both individual truck and average percent time spent in each of the modes for nine different groupings of the data are contained in Appendix E as Tables E-1 through E-9. Also shown are the minimum, maximum, and standard deviation for each group. The average percent time in mode for each group is shown in Table 102.

The 13-mode weighting factors were then calculated from these average percent time-in-mode values. The percent time at idle is used as the idle weighting factor since it is assumed that all idle time in the operating matrix is used in determining the percent time at idle. Because the remaining modes do not represent all of the non-idle operation of the vehicle, the percent time-in-mode cannot be used as a weighting factor. However, if the total vehicle non-idle operating time is divided by the total time in the non-idle modes, a multiplication factor is obtained. This factor can be applied to the percent time in each of the non-idle modes to yield a weighting factor. Note that the 13-mode test contains no motoring mode. Nor should it, since the fuel is essentially shut off at motoring. Therefore, the time spent in motoring is not used in the above procedure; and the 11 modes are assumed to represent 100 percent of the truck operation. The 10 non-idle modes, therefore, represent 100 percent time minus the idle percent time. Note that this does not mean the emissions of HC, CO, and NO_x are zero at motoring conditions, only that the fuel rate at the motoring condition is negligible.

The modal weighting factors thus obtained are shown in Table 103 for the various groups of trucks. These weighting factors, then, are the 13-mode weighting factors representing the percent time-in-mode experienced by the trucks tested in the CAPE-21 project. The current 13-mode heavy-duty FTP weighting factors are shown for comparison. Also shown are the weighting factors from 12 diesel trucks tested under Contract 68-03-2147. These weighting factors were developed by optimizing the relationship between modal fuel and 32 kph driving cycle fuel rate.

As can be seen from the table, the differences in the New York and Los Angeles weighting factors at idle; 75 percent power at intermediate speed; and 25, 50, and 75 percent power at rated speed are greater than the difference between single unit and tractor-trailer trucks within either

TABLE 102 . AVERAGE PERCENT TIME SPENT IN MODES OF THE 13-MODE FTP FOR CAPE-21 DIESEL TRUCKS

Data Base	Idle	Average Percent Time in Mode										Modal Total
		Intermediate rpm Power					Rated rpm Power					
		2	25	50	75	100	2	25	50	75	100	
NY + LA (all)	28.25	0.57	2.05	0.79	1.60	0.42	0.69	3.09	1.97	3.94	1.96	45.32
NY + LA (SU)*	33.45	0.63	1.93	0.75	1.95	0.59	0.38	3.22	2.18	4.23	1.93	51.26
NY + LA (TT)**	24.96	0.53	2.13	0.81	1.38	0.31	0.88	3.00	1.84	3.75	1.97	41.56
LA (all)	17.07	0.56	2.13	0.72	1.03	0.38	0.87	4.99	3.12	5.76	2.26	38.88
LA (SU)	20.58	0.61	1.83	0.59	0.75	0.58	0.66	5.25	3.63	6.63	3.19	44.32
LA (TT)	15.16	0.53	2.29	0.78	1.17	0.26	0.99	4.85	2.84	5.28	1.75	35.91
NY (all)	41.82	0.57	1.96	0.87	2.30	0.47	0.46	0.78	0.57	1.73	1.59	53.13
NY (SU)	46.32	0.65	2.04	0.91	3.15	0.60	0.10	1.20	0.72	1.84	0.67	58.20
NY (TT)	38.44	0.52	1.90	0.85	1.66	0.37	0.73	0.46	0.46	1.65	2.28	49.33

---

* SU - Single Unit
** TT - Tractor

TABLE 103 . SUMMARY OF 13-MODE WEIGHTING FACTORS CALCULATED FROM CAPE-21 DATA

		Modal Weighting Factor									
		Intermediate rpm Power					Rated rpm Power				
Data Base	Idle	2	25	50	75	100	2	25	50	75	100
NY + LA (all)	0.283	0.024	0.086	0.033	0.067	0.018	0.029	0.130	0.083	0.166	0.082
NY + LA (SU)*	0.335	0.024	0.072	0.028	0.072	0.022	0.014	0.120	0.082	0.158	0.074
NY + LA (TT)**	0.250	0.024	0.963	0.037	0.062	0.014	0.040	0.136	0.535	0.170	0.089
LA (all)	0.171	0.021	0.081	0.027	0.039	0.014	0.033	0.190	0.119	0.219	0.086
LA (SU)	0.206	0.020	0.061	0.020	0.025	0.019	0.022	0.176	0.122	0.222	0.107
LA (TT)	0.152	0.022	0.094	0.032	0.048	0.011	0.041	0.198	0.116	0.216	0.072
NY (all)	0.418	0.029	0.101	0.045	0.118	0.024	0.024	0.040	0.029	0.089	0.082
NY (SU)	0.463	0.029	0.092	0.041	0.142	0.027	0.005	0.054	0.033	0.083	0.030
NY (TT)	0.384	0.029	0.107	0.048	0.094	0.021	0.041	0.026	0.026	0.093	0.129
Optimized 32 kph***	0.192	0.384	0.000	0.000	0.177	0.000	0.130	0.000	0.000	0.000	0.199
Federal Register	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

---

* SU - Single Unit

** TT - Tractor

*** Diesel truck data from Contract 68-03-2147--weighting factors optimzed by regression analysis to give best correlation between 32 kph half load fuel consumption and 13-mode fuel consumption one of the cities. Since there is a greater difference between cities than between vehicle types and information for weighting each city's driving patterns is not available, it is felt that the overall combined New York and Los Angeles weighting factors are probably the best one to use.

The 13-mode data from the 12 diesel trucks tested under Contract 68-03-2147 were reprocessed using these new weighting factors to determine if the new composite 13-mode BSFC would correlate with driving cycle fuel economy. The new composite 13-mode BSFC values are presented in Table 104, together with the BSFC values using the 13-mode FTP weighting factors and the weighting factors obtained from the optimization study presented in Section IV of this report. Note that the BSFC values in the table are in terms of kilograms per kilowatt hour. There is little difference in BSFC between trucks. The coefficient of variation varies from 4 to 6 percent depending on the method used. The turbocharged trucks all have a lower BSFC than the nonturbocharged trucks. When BSFC is averaged for the nonturbocharged engines separately, the coefficient of variation for the BSFC using CAPE-21 weighting factors is 2.4 percent. The BSFC values calculated using the CAPE-21 weighting factors differ only slightly from the BSFC values using the FTP weighting factors for each individual truck. Using the FTP value as a standard, the maximum difference was -2.8 percent for Truck 26. The differences in BSFC values using the optimized weighting factors were somewhat greater, the largest difference being 19.3 percent, again, for Truck 26.

It is logical to expect that fuel economy, or its inverse, fuel consumption, in actual vehicle operation would be a function of vehicle weight. Indeed, this was demonstrated on a previous project.(11) The trucks tested under Contract 68-03-2147 also show this relationship as seen in Figure 44. For each truck, the 32 kph driving cycle test weights and corresponding fuel rates are listed in Appendix E as Table E-10. Figure 44, the fuel rate in grams/minute, from a 32 kph average speed driving cycle is plotted against vehicle weight in kilograms. Because there is a definite BSFC difference between the turbocharged and nonturbocharged engines, only the nonturbocharged engines were used in this analysis to avoid introducing additional variables. Truck 30 was not included because of some question about the 32 kph fuel rate data. Since each truck was tested at three different inertia weights, it is possible to determine the relationship between 32 kph fuel rate and vehicle weight for each truck.

For purposes of comparing the 13-mode BSFC with driving cycle fuel rate, a vehicle weight of 12,000 kg was chosen as a convenient weight which would require a minimum of extrapolation to include most of the trucks. The 32 kph fuel rate for each truck at a vehicle weight of 12,000 kg is shown in Table 104.

The BSFC and 32 kph fuel rate values shown in Table 104 are plotted as Figure 45 for better comparison. As can be seen from the figure, the 13-mode composite BSFC and 32 kph driving cycle fuel rate do not show good correlation for any of the three methods used to obtain a composite BSFC.

Using the experience gained from a similar analysis done for CAPE-21 gasoline-powered trucks (Section V of this report), it was felt that the vehicle weight to engine power ratio was an important variable to consider. Table 105 shows the maximum power at rated speed for each truck tested. The vehicle weight to engine power ratio for the three inertia weights

TABLE 104. COMPARISONS OF 13-MODE BSFC USING DIFFERENT WEIGHTING FACTORS FOR 12 DIESEL TRUCKS

		13-Mode Composite BSFC(kg/kw-hr)using:			32 kph
Truck No.	Turbocharged	1974 FTP Weighting Factor	CAPE-21 % Time W. F.	Optmized 32 kph* W. F.	Driving Cycle Fuel g/min**
19	No	0.284	0.280	0.329	---
20	Yes	0.265	0.267	0.296	227
21	Yes	0.262	0.264	0.288	246
22	Yes	0.268	0.272	0.304	218
23	No	0.291	0.285	0.343	231
24	No	0.277	0.272	0.318	222
25	Yes	0.262	0.264	0.293	239
26	No	0.285	0.277	0.340	196
27	No	0.277	0.280	0.322	209
28	No	0.277	0.282	0.311	183
29	No	0.286	0.289	0.336	156
30	No	0.295	0.294	0.327	161
Average		0.277	0.277	0.317	
S.D.		0.011	0.010	0.019	
C. of V.		4.0%	3.5%	5.9%	
Average Non-Turbo(8)		0.284	0.282	0.328	
S.D.		0.007	0.007	0.011	
C. of V.		2.4%	2.4%	3.8%	
Average Turbo (4)		0.264	0.267	0.295	
S.D.		0.003	0.004	0.007	
C. of V.		1.1%	1.4%	2.3%	

*Weighting factors determined from optimizing relationships of modal fuel and 32 kph driving cycle fuel rate.

**At 12000 kg test weight

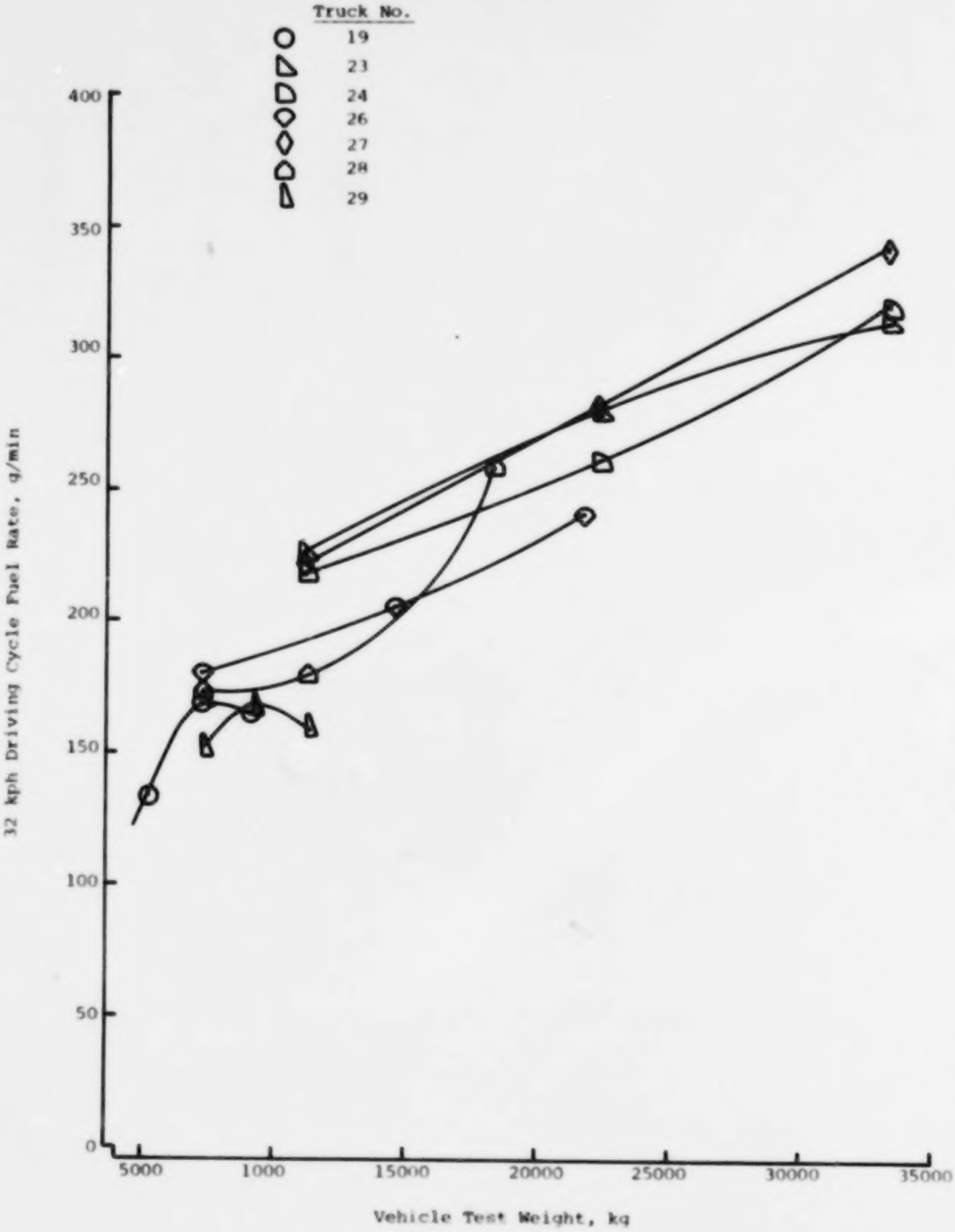


FIGURE 44. 32 kph DRIVING CYCLE FUEL RATE AS A FUNCTION OF VEHICLE TEST WEIGHT FOR SEVEN NONTURBOCHARGED DIESEL TRUCKS

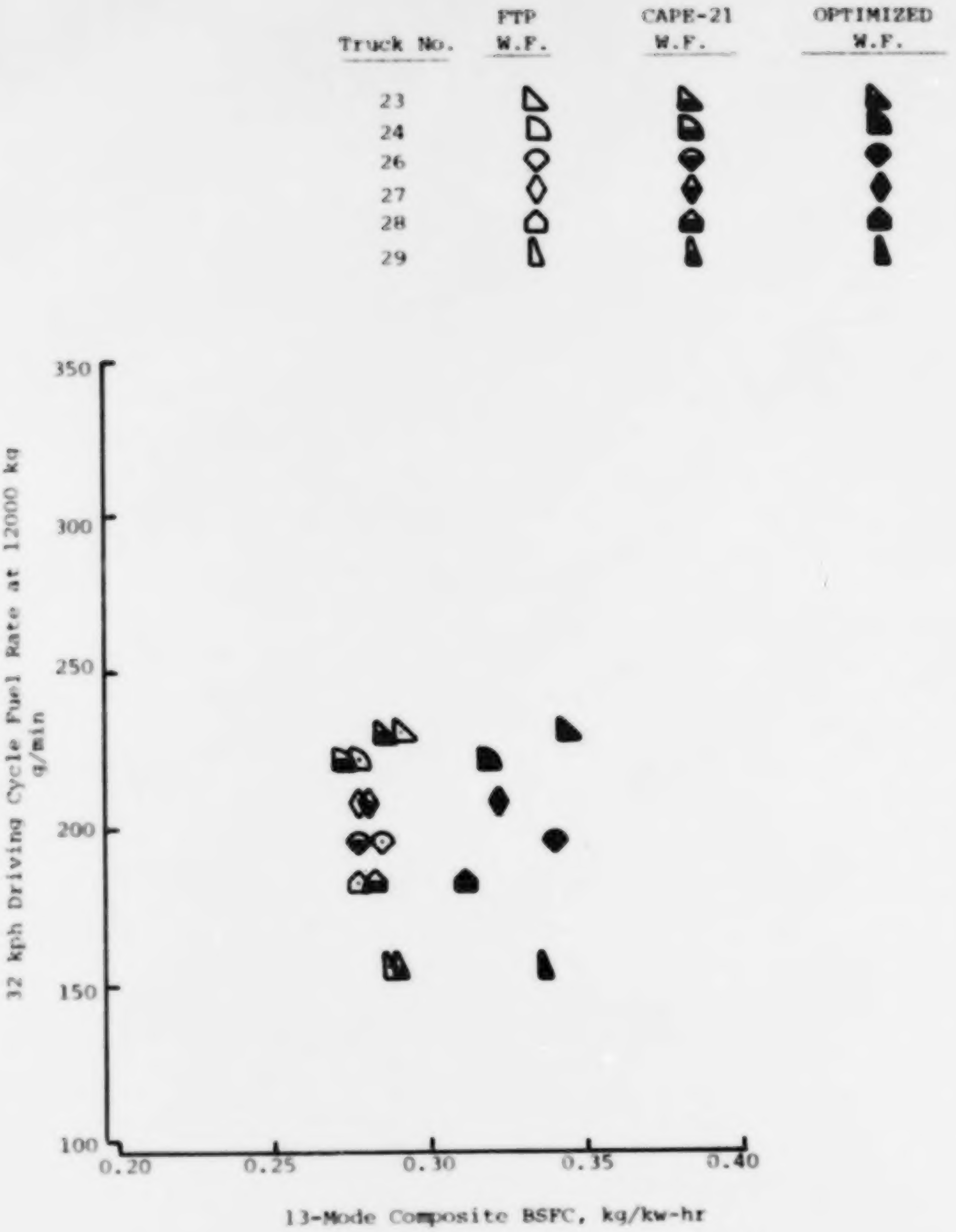


FIGURE 45. 32 kph FUEL RATE AS A FUNCTION OF 13-MODE COMPOSITE BSFC FOR SIX NONTURBOCHARGED DIESEL TRUCKS

TABLE 105. RATED POWER OF 12 DIESEL TRUCKS TESTED UNDER CONTRACT 68-03-2147

Truck No.	Turbocharged	Max. Power @ Rated RPM Kw	Weight/Power Ratio, kg/kw		
			Empty Load	Half Load	Full Load
19	No	133	39.3	54.7	68.4
20	Yes	266	41.7	83.7	125.6
21	Yes	227	48.9	97.7	146.6
22	Yes	172	64.5	129.0	193.6
23	No	209	53.2	106.5	159.7
24	No	219	50.7	101.4	152.1
25	Yes	216	51.6	103.1	154.7
26	No	155	46.8	93.6	140.4
27	No	230	48.4	96.8	145.1
28	No	134	54.1	82.8	136.9
29	No	124	58.6	75.1	89.8
30	No	145	49.9	76.4	126.3

tested on each truck is also shown. The 32 kph driving cycle fuel rate for 7 of the non-turbocharged trucks is plotted as a function of the vehicle weight to engine power ratio for each truck in Figure 46. From the figure it can be seen that in general, the 32 kph fuel rate increases as weight to power ratio increases. As with the plot of fuel rate versus vehicle weight, the trucks seem to be ordered by engine power with the higher power engines giving a higher 32 kph fuel rate.

The 32 kph fuel rate at a constant weight to power ratio of 60.0 is plotted as a function engine maximum power in Figure 47. It appears that there is a good relationship between engine maximum power and the 32 kph driving cycle fuel rate at a constant weight to power ratio. But, it can be shown that the 13-mode composite fuel rate using the CAPE-21 weighting factors is also a function of engine maximum power at rated speed. See Figure 48. Note that the scatter about the estimated 0.280 kg/kw-hr BSFC line is apparently a function of BSFC. The composite 13-mode fuel rate from the three sets of weighting factors is listed in Table 106.

The 32 kph driving cycle fuel rate at three constant weight to power ratios is plotted in Figure 49 as a function of the 13-mode composite fuel rate for 7 non-turbocharged diesel engines. Note that there is a definite relationship between the 13-mode composite fuel rate and the 32 kph fuel rate at a constant weight to power ratio. However, there is some scatter in the data. If it is hypothesized that the relationship is also a function of BSFC, and a line of constant BSFC drawn through the date, the scatter about the line appears to be caused by differences in BSFC.

Thus it appears that truck fuel consumption (or alternately fuel economy) on the road is a function of vehicle weight, engine power, and specific fuel consumption (i.e., thermal efficiency). It is felt that the data presented here is not sufficient to accurately define these relationships. However, the trucks tested under Contract 68-03-2147 do represent a large portion of the diesel engine makes currently in use. Considering the small differences in BSFC seen between engines, it appears that optimum engine to vehicle matching may be more important than BSFC in obtaining the best available fuel economy for a given vehicle.

The above analysis used the BSFC and composite fuel rate calculated from the CAPE-21 derived weighting factors. The question arises as to whether the other weighting factors presented in Table 103 would give as good results. To answer this question, the composite fuel consumption from the FTP and optimized weighting factors was plotted versus the 32 kph driving cycle fuel rate at a weight to power ratio of 60.0 in Figures 50 and 51. From the figures it appears that CAPE-21 weighting factors give a better relationship than the FTP weighting factors and about equally as good a relationship as the optimized weighting factor. The 32 kph driving cycle was reportedly developed from CAPE-21 data. The fact that the percent time in mode from the CAPE-21 data gives a composite fuel consumption that correlates with a 32 kph cycle developed from CAPE-21 data when vehicle weight and engine power are also considered, gives credence to the method used to determine the modal weighting factors.

The remaining item in this study is to identify additional modes that

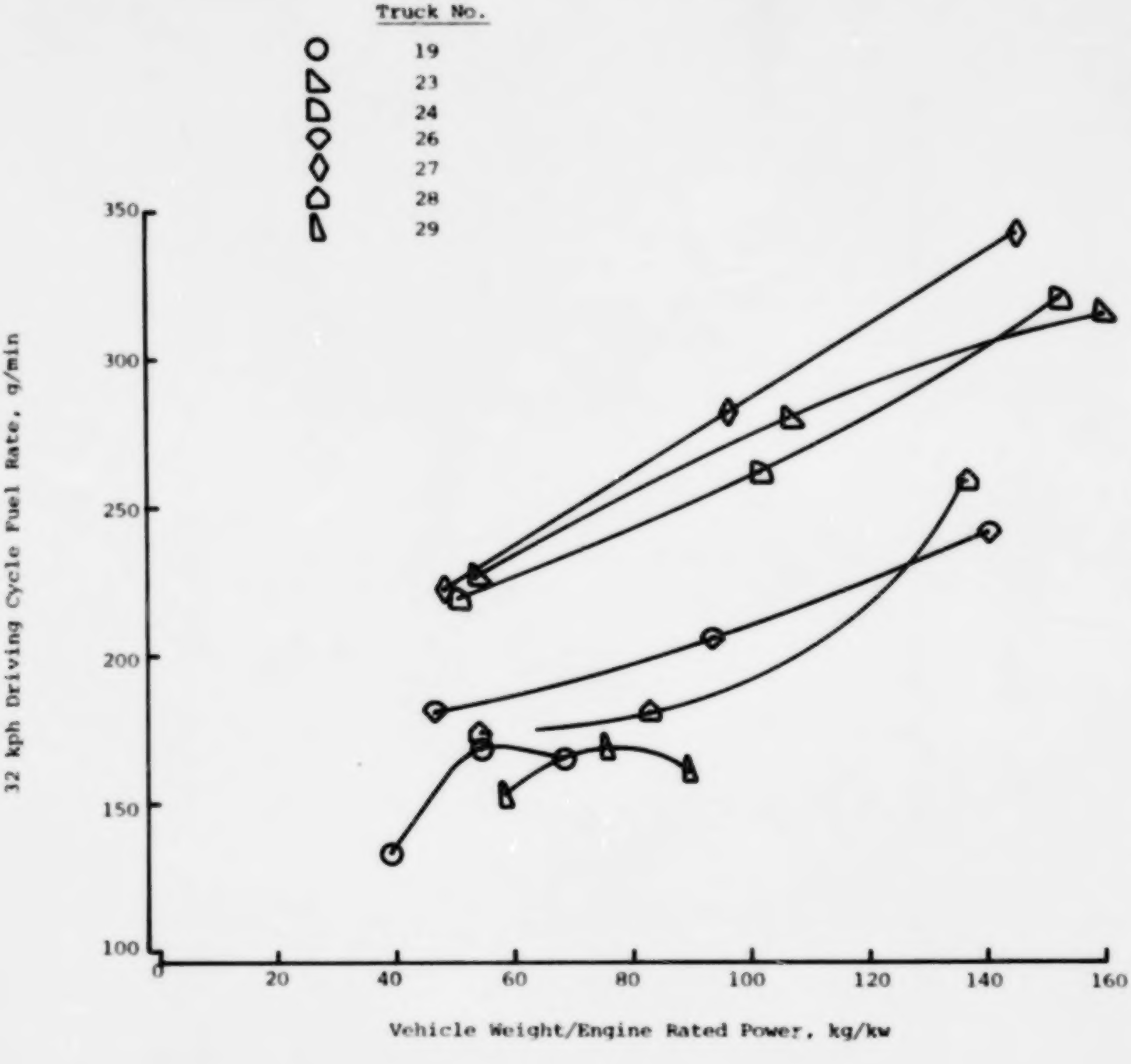


FIGURE 46. 32 kph DRIVING CYCLE FUEL RATE AS A FUNCTION OF WEIGHT/POWER RATIO FOR SEVEN NONTURBOCHARGED DIESEL TRUCKS

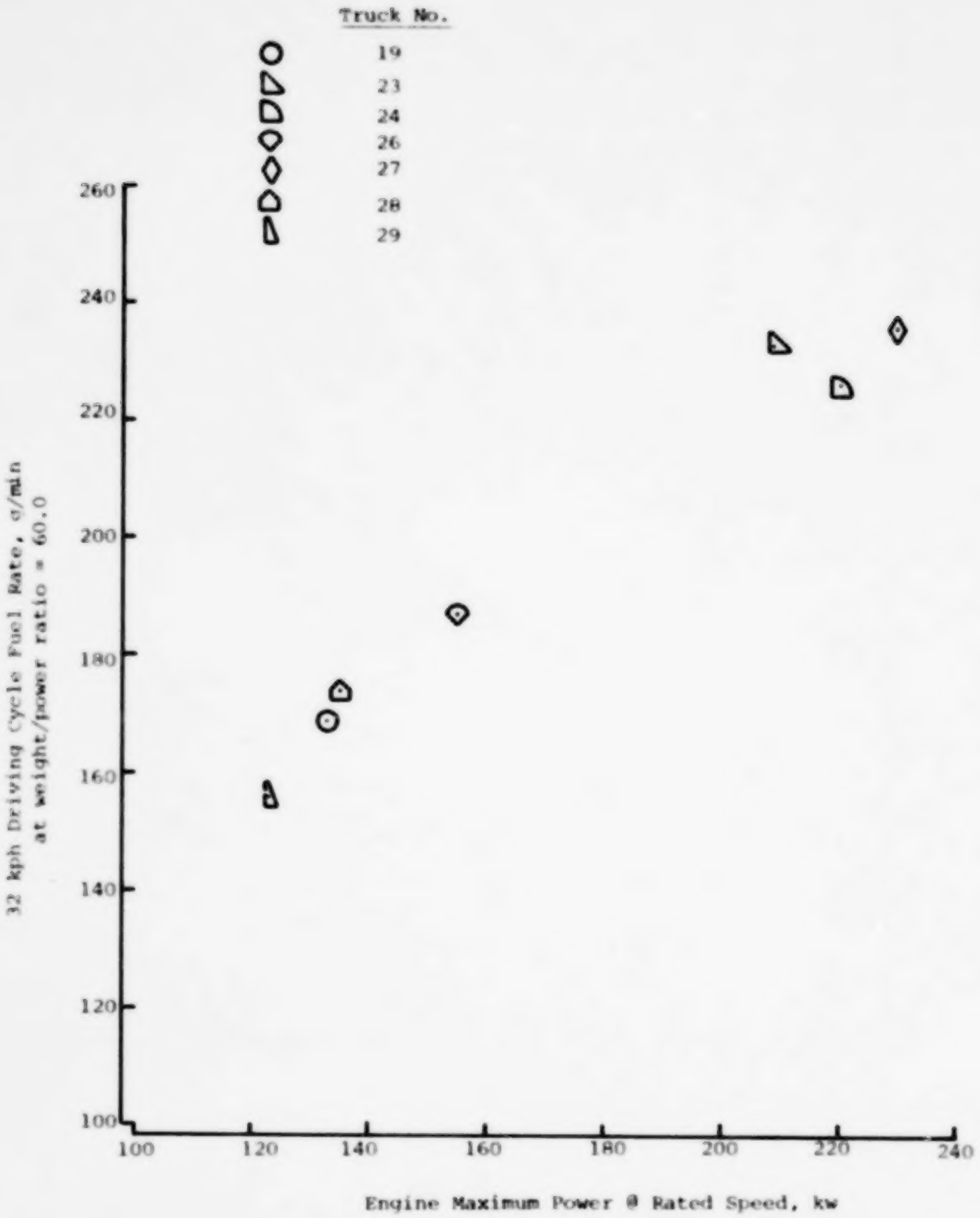


FIGURE 47. 32 kph DRIVING CYCLE FUEL RATE AT CONSTANT WEIGHT/POWER RATIO AS A FUNCTION OF ENGINE RATED POWER

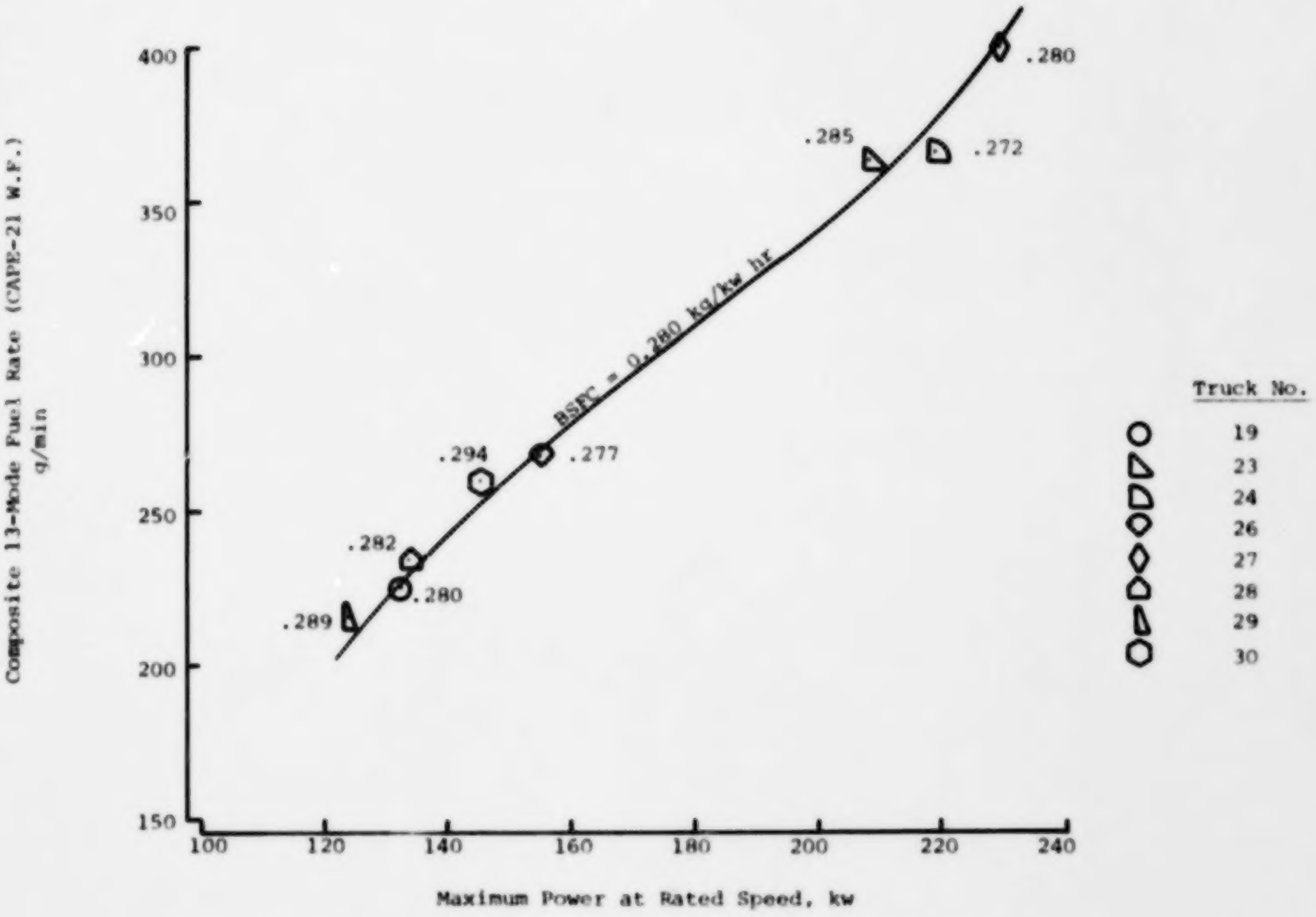


FIGURE 48. COMPOSITE 13-MODE FUEL RATE AS A FUNCTION OF ENGINE RATED SPEED FOR EIGHT NONTURBOCHARGED DIESEL ENGINES

TABLE 106. COMPOSITE 13-MODE FUEL RATE USING THREE SETS OF WEIGHTING FACTORS FOR 12 DIESEL TRUCKS

Truck No.	Turbocharged	Composite 13-Mode Fuel Rate, g/min FTP Weighting Factor	CAPE-21 Weighting Factor	Optimized Weighting Factor
19	No	224	225	181
20	Yes	433	437	324
21	Yes	377	375	307
22	Yes	295	294	234
23	No	370	364	301
24	No	372	366	294
25	Yes	363	358	291
26	No	277	268	225
27	No	400	401	314
28	No	233	235	190
29	No	209	216	170
30	No	260	260	209

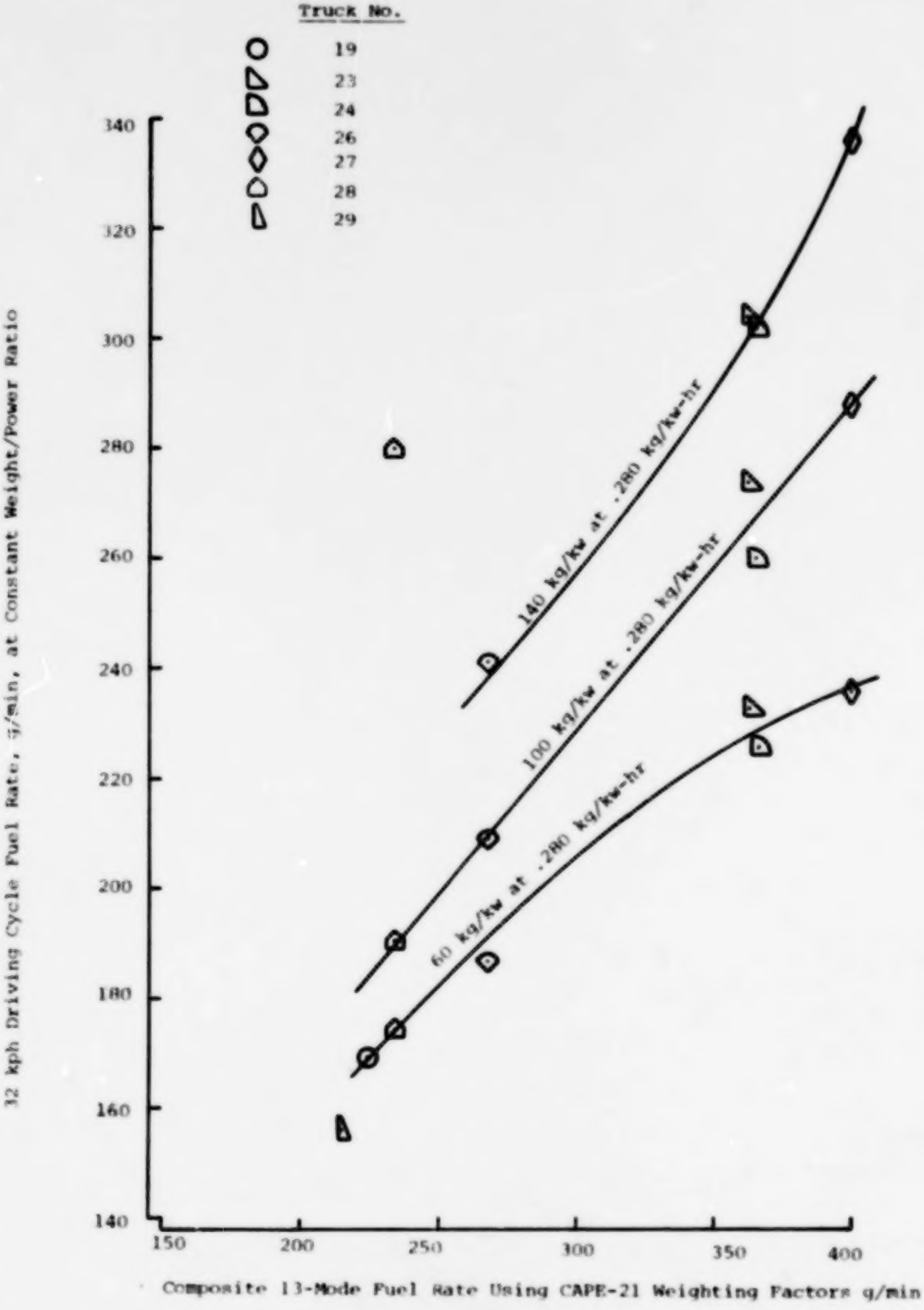


FIGURE 49. 32 kph DRIVING CYCLE FUEL RATE AT CONSTANT WEIGHT/POWER RATIO VERSUS COMPOSITE 13-MODE FUEL RATE USING CAPE-21 WEIGHTING FACTORS

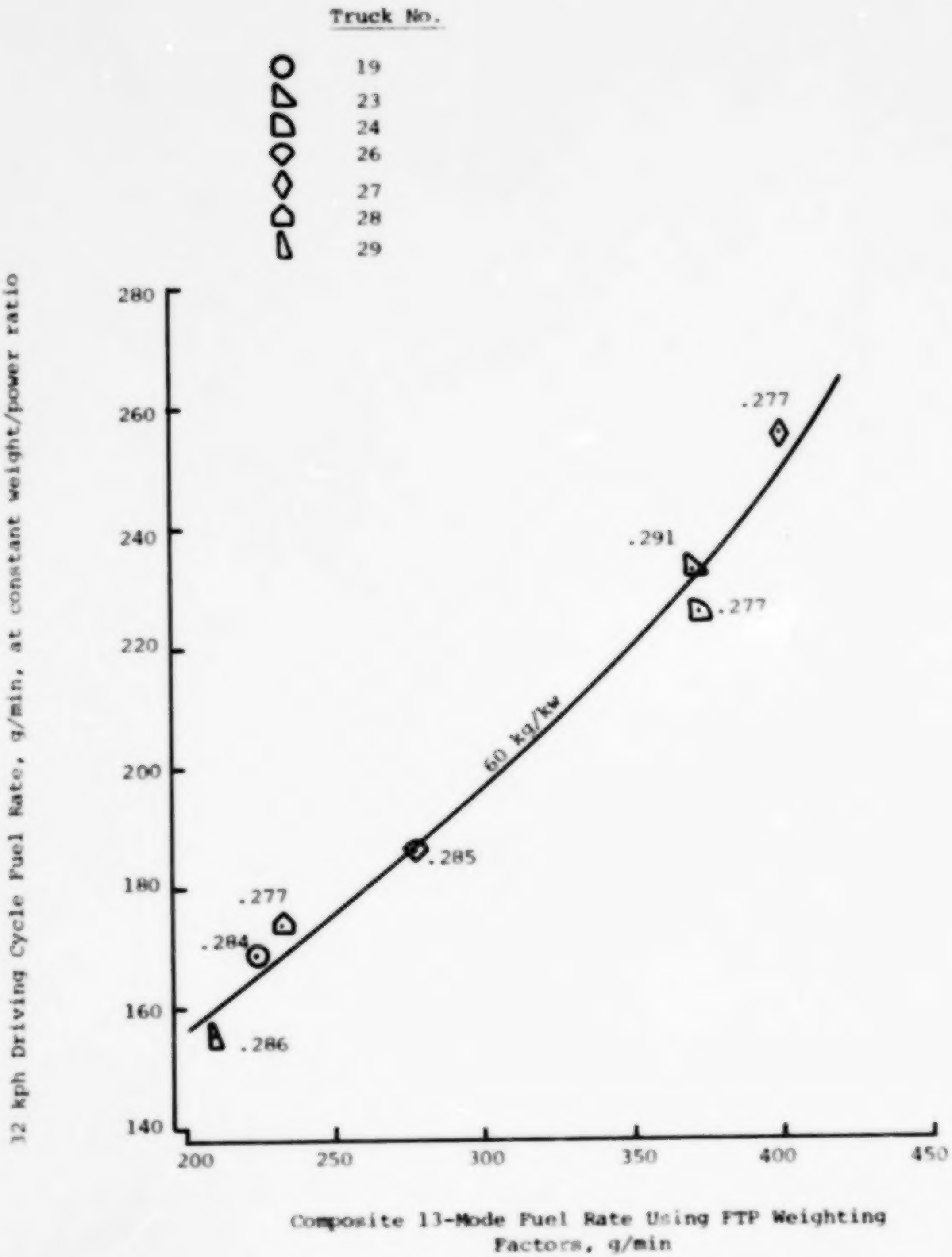


FIGURE 50. 32 kph DRIVING CYCLE FUEL RATE AT CONSTANT WEIGHT/POWER RATIO VERSUS COMPOSITE 13-MODE FUEL RATE USING FTP WEIGHTING FACTOR

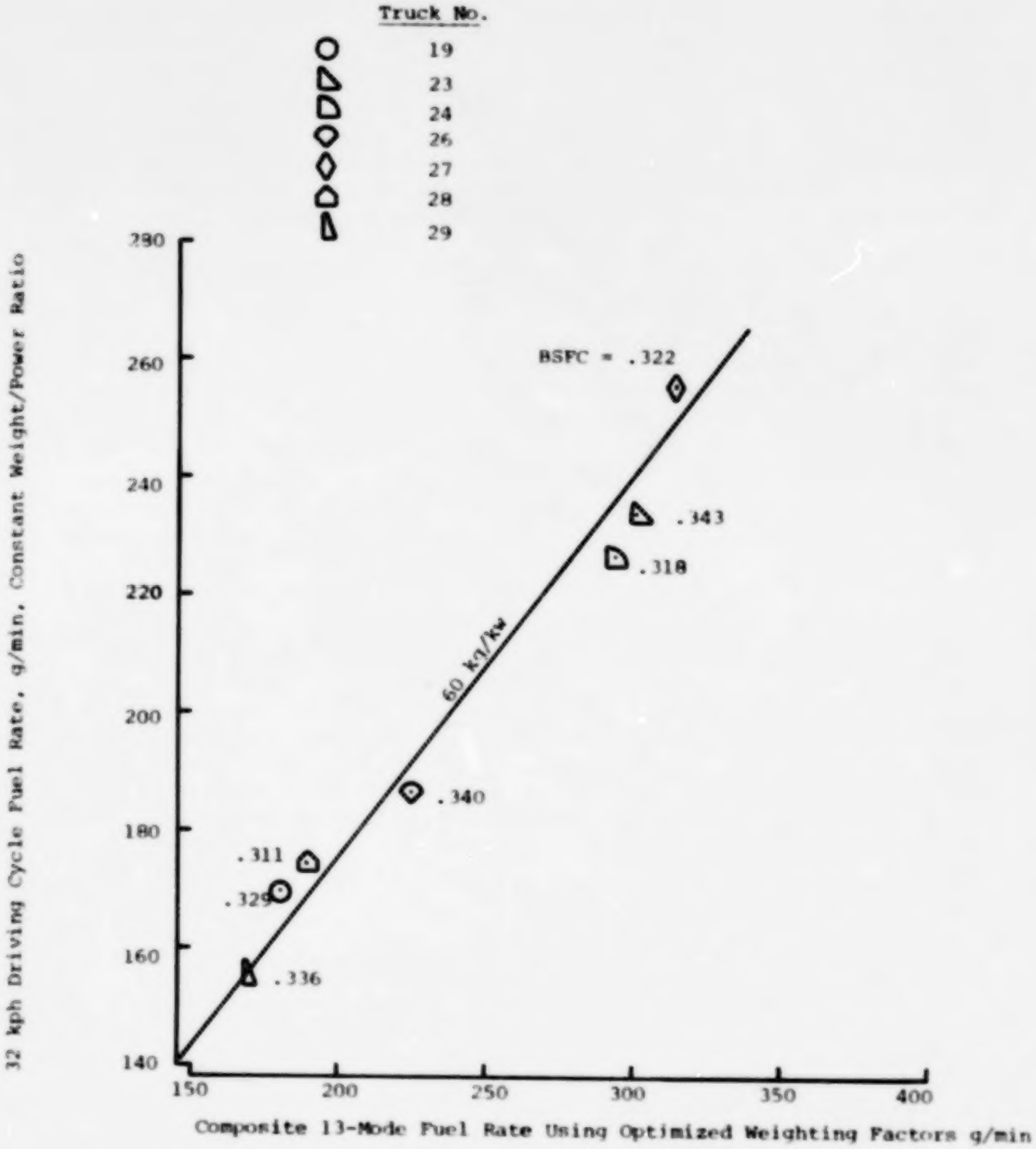


FIGURE 51. 32 kph DRIVING CYCLE FUEL RATE AT CONSTANT WEIGHT/POWER RATIO VERSUS COMPOSITE 13-MODE FUEL RATE USING OPTIMIZED WEIGHTING FACTORS

would increase the percent operating time (as defined by the average CAPE-21 percent time matrix) represented in the diesel modal test. An examination of Table 95 indicates several operating areas where the CAPE-21 trucks spent a proportionally large amount of time. It is immediately obvious that 80 percent of rated speed line (75 to 85 percent speed interval) contains a good deal of operating time. To suggest additional modes at this speed, however, would not be in keeping with the guidelines that additional modes add a minimun of cost, time and complexity. Since the areas of matrix represented by the 13-mode test were somewhat arbitrarily chosen, the 80 percent speed areas could be covered by simply extending the 100 percent rated speed mode representation to include the 80 percent speed cells. There are 4 additional power modes at rated speed that would add significantly to the percent time represented by the diesel modal test. These modes are 90, 60, 40, and 10 percent power, all at rated speed. In addition one mode at idle speed and 15 percent power would seem to be needed.

The total area covered by the 13-mode test was shown previously to be 45.32 percent for the overall CAPE-21 study. This is 57.03 percent of the total non-motoring time. The five new modes, plus the extension of the rated power area, gives a new total operating time covered of 65.91 percent or 82.62 percent of the total nonmotoring time. The percent time represented by each by each mode is shown in Table 107. Of course, more or less time could be used for the total time represented, if the area of each of the modes were changed. It is obvious, however, that the five new modes are in areas of relatively high percent operating time.

To summarize this part of the project, it was found that there is no direct relationship between the 13 composite BSFC (regardless of weighting factors used) and vehicle fuel consumption (or fuel economy). Rather, vehicle fuel consumption is a function of vehicle weight, engine power and thermal efficiency (represented by composite BSFC). A relationship was obtained between vehicle fuel rate on a 32 kph driving cycle developed from CAPE-21 and the 13-mode composite BSFC using CAPE-21 derived weighting factors with vehicle weight and engine power also included as variables. However, this is an empirical relationship developed from only seven non-turbocharged diesel engines. More data is needed before a satisfactorily precise relationship can be developed. Finally, the study indicated that for diesel engines now in use, proper engine to vehicle matching is more important in obtaining the best available fuel economy than engine to engine differences in BSFC.

TABLE 107. PERCENT OF CAPE-21 TRUCK OPERATING TIME REPRESENTED BY VARIOUS PERCENT ENGINE SPEED AND PERCENT POWER MODES

Mode	Speed	Percent Power	Percent Time*
I. Modes of the 13 Mode FTP			
1, 7, 13	Idle	0	28.25
2	Intermediate	2	.57
3	Intermediate	25	2.05
4	Intermediate	50	.79
5	Intermediate	75	1.60
6	Intermediate	100	.42
8	Rated	100	1.96
9	Rated	75	3.94
10	Rated	50	1.97
11	Rated	25	3.09
12	Rated	2	.69
		Total 13 Mode	45.32
		Total Nonmotoring	57.03
II. Suggested Additional Mode			
	Idle	15	2.12
	Rated	10	1.95
	Rated	40	2.98
	Rated	60	3.02
	Rated	90	4.28
		Total Additional Modes	14.35
III. Additional Time from Increased Area of Rated Speed			6.22
IV. Total Percent Time			65.91
V. Percent of Total Nonmotoring Time			82.62

*From all CAPE-21 diesel trucks tested in Los Angeles and New York

LIST OF REFERENCES

1. Springer, Karl J., "An Investigation of Emissions from Trucks Above 6000 lb GVW Powered by Spark-Ignited Engines." Final Report to the Department of Health, Education, and Welfare under Contract No. PH 86-67-72, March 1969.

2. Springer, K. J., Williams, G. L., Olsen, Robert W., and Mills, Kenneth D., "Emissions from Gasoline-Powered Trucks Above 10,000 lb GVW Using PHS Proportional Sampling Techniques." Paper 53C presented at AIChE Symposium on Research and Development in Automotive Air Pollution Control--61st Annual Meeting, Los Angeles, December 1-5, 1968.

3. Olsen, Robert W. and Springer, Karl J., "Exhaust Emissions from Heavy-Duty Vehicles." Paper 690764 presented at SAE National Combined Fuels and Lubricants and Transportation Meetings, Houston, November 4-7, 1969.

4. Tyree, Clifford D. and Springer, Karl J., "Studies of Emissions from Gasoline-Powered Vehicles Above 6000 lb Gross Vehicle Weight." Final Report to the Department of Health, Education, and Welfare under Contract No. PH 86-67-72, July 1970.

5. Springer, Karl J. and Tyree, Clifford D., "Exhaust Emissions from Gasoline-Powered Vehicles Above 6000 lb Gross Vehicle Weight." Final Report to the Environmental Protection Agency under Contract No. EHS 70-110, April 1972.

6. Springer, Karl J., "Baseline Characterization and Emissions Control Technology Assessment of HD Gasoline Engines." Final Report to the Environmental Protection Agency under Contract No. EHS 70-110, November 1972.

7. Ingalls, Melvin N. and Springer, Karl J., "In-Use Heavy-Duty Gasoline Truck Emissions." Final Report Part I (Mass Emissions From Trucks Operated Over a Road Course) to the Environmental Protection Agency under Contract No. EHS 70-113, February 1973.

8. Storment, John O. and Springer, Karl J., "A Surveillance Study of Smoke from Heavy-Duty Diesel-Powered Vehicles - Southwestern U.S.A." Final Report to the Environmental Protection Agency under Contract No. EHS 70-109, June 1973.

9. Ingalls, Melvin N., "Baseline Emissions on 6,000 to 14,000 Pounds Gross Vehicle Weight Trucks." Final Report to the Environmental Protection Agency under Contract No. 68-01-0467, June 1973.

10. Urban, Charles M., Springer, Karl J., and Montalvo, Daniel A., "Emissions Control Technology Assessment of Heavy-Duty Vehicle Engines." Final Report No. EPA-460/3-74-007 to the Environmental Protection Agency under Contract No. 68-03-0472, December 1973.

11. Ingalls, Melvin N. and Springer, Karl J., "Mass Emissions From Diesel Trucks Operated Over a Road Course." Final Report No. EPA-460/3-74-017 to the Environmental Protection Agency under Contract No. 68-01-2113, August 1974.

12. Ingalls, M. N. and Springer, K. J., "Mass Emissions From Ten Pre-Controlled Gasoline Trucks, and Comparisons Between Different Trucks on a Road Course." Final Report to the Environmental Protection Agency under Contract No. 68-03-0441, April 1975.

13. Urban, Charles M. and Springer, Karl J., "Study of Emissions From Heavy-Duty Vehicles." Final Report No. EPA-460/3-76-012 to the Environmental Protection Agency under Contract No. 68-03-2147, May 1976.

14. Urban, Charles M. and Springer, Karl J., "13-Mode Diesel Emission Test Results on 12 Trucks." Final Report to the Engine Manufacturers Association under EMA Contract, February 20, 1976.

15. CRC APRAC Status Report, Coordinating Research Council, Inc., January 1976.

16. Ethyl Corporation, "Survey of Truck and Bus Operating Modes in Several Cities." Final Report No. GR 63-24 to the U.S. Public Health Service under Contract No. PH 86-62-12, June 1963.

17. Ravindran, Arunachalum, "A Computer Routine for Quadratic and Linear Programming Problems." *Communication of the Association of Computing Machinery*, Algorithm 431, Vol. 15, September 1972, pp. 818-820.

18. Daniel, Cuthbert and Wood, Fred S., *Fitting Equations to Data*, John Wiley and Sons, Inc, New York, 1971, Chapter 8.

19. Ingalls, Melvin N. and Springer, Karl J., "In-Use Heavy-Duty Gasoline Truck Emissions." Final Report Part II (Surveillance Study of Control Equipped Heavy-Duty Gasoline-Powered Vehicles), No. EPA-460/3-002-b, to the Environmental Protection Agency under Contract No. EHS 70-113, June 1974.

20. Motor Vehicle Manufacturers Association, "Historical Development of Heavy-Duty Gasoline Engine Dynamometer Emissions Test Cycle and Emissions Standards", undated.

21. Khuri, A. I., "A Constrained Least Squares Problem." *Communications in Statistics*, pages 82 to 84, Volume B5, Number 1.

22. Siegel, Sidney, *Nonparametric Statistics*, McGraw-Hill Book Company, Inc., New York, 1956, pages 127-136.

23. France, Chester, "Engine Horsepower Modeling for Diesel Engines." EPA Technical Support Report for Regulatory Action, No. HDV 76-03, October 1976.

APPENDIX A

DESCRIPTION OF VEHICLES TESTED AND LISTING OF SPECIAL COMPUTER PROGRAMS

TABLE A-1. DESCRIPTION OF GASOLINE-POWERED VEHICLES TESTED UNDER CONTRACT 68-03-2147

No.	Desc.*	Year	Make	Engine
1	D2GAS	1970	Dodge	Dodge - 318
2	D2GAS	1974	Chevrolet	Chevrolet - 366
3	D2GAS	1973	Ford	Ford - 361
4	D2GAS	1975	IHC	IHC - 345
5	D2GAS	1965	Chevrolet	Chevrolet - 292
6	D2GAS	1975	Ford	Ford - 391
7	D2GAS	1974	IHC	IHC - 392
8	D2GAS	1974	Dodge	Dodge - 361
9	D3GAS	1973	IHC	IHC - 345
10	TTGAS	1974	IHC	IHC - 478
11	D3GAS	1974	Chevrolet	Chevrolet - 366
12	TTGAS	1972	Ford	Ford - 477
13	TTGAS	1974	GMC	GMC - 427
14	TTGAS	1969	Ford	Ford - 391
15	D3GAS	1974	GMC	GMC - 427
16	D3GAS	1966	Chevrolet	Chevrolet - 366
**17	D2GAS	1975	IHC	IHC - 345
**18	TTGAS	1975	Ford Cal.	Ford - 389

---

* Description Code:

D2GAS - Single Unit, Two-Axle Gasoline Truck

D3GAS - Single Unit, Three-Axle Gasoline Truck

TTGAS - Gasoline Truck Tractor (All Two-Axle) Used
with Single-Axle Trailer During Road Work

** Meets California Emission Requirements

TABLE A-2. DESCRIPTION OF DIESEL TRUCKS TESTED UNDER EPA CONTRACT 68-03-2147

No.	Description*	Year	Make	Engine
19	D2DIE	1972	Ford	Caterpillar 1150
20**	TTDIE	1975	Ford	Cummins NTCC-350
21	TTDIE	1973	IH	Cummins NTC-290R
22	TTDIE	1971	Mack	Mack ENDT-675
23	TTDIE	1972	IH	Detroit Diesel 8V-71N
24	TTDIE	1975	Ford	Detroit Diesel 8V-71N
25	TTDIE	1975	IH	Cummins NTC-290R
26	TTDIE	1974	Ford	Detroit Diesel 6L-71N
27	TTDIE	1972	IH	Cummins V8-903
28	D3DIE	1967	Dodge	Cummins NH-220
29	D2DIE	1975	IH	Caterpillar 3208
30	D3DIE	1975	IH	Detroit Diesel 6V-53N
31	Bus	1972	GMC	Detroit Diesel 6V-71N
32	Bus	1975	MCI	Detroit Diesel 8V-71N

---

*Description Code:

D2DIE - Single Unit, Two-Axle Diesel Truck

D3DIE - Single Unit, Three-Axle Diesel Truck

TTDIE - Diesel Truck-Tractor (All but one were 3-Axle)
Used with Tandem-Axle Trailer During Road Work

Bus - Two-Axle Diesel Bus

**Meets California Emission Requirements

TABLE A-3. DESCRIPTION OF CAPE-21 TRUCKS TESTED IN NEW YORK CITY

Truck No.	Fuel	Model Year	Body Type	GVW	Body Mfgr.	Engine Mfgr.	Engine Size
2	Gasoline	71	SU	16660	IHC	IHC	391
3	Gasoline	70	SU	17990	IHC	IHC	304
4	Gasoline	66	SU	13000	Chev.	Chev.	292
5	Gasoline	69	SU	18000	Dodge	Dodge	318
6	Gasoline	72	SU	14000	IHC	IHC	304
7	Gasoline	70	TT	50000	Ford	Ford	477
8	Gasoline	69	SU	17990	Chev.	Chev.	350
9	Gasoline	52	SU	19500	Mack	Mack	510
11	Gasoline	74	SU	19700	IHC	IHC	304
12	Gasoline	73	SU	17820	IHC	IHC	345
13	Gasoline	73	SU		GMC	Chev.	379
16	Gasoline	66	SU	24000	IHC	IHC	345
17	Gasoline	69	SU	10000	Ford	Ford	361
20	Gasoline	69	SU	10000	GMC	Chev	
25	Gasoline	67	SU		White	D. Reo	400
26	Gasoline	61	SU	58900	Mack	Mack	540
27	Diesel	69	TT			Cummins	464
28	Gasoline	74	SU	48860	IHC	IHC	477
29	Gasoline	64	SU		White	D. Reo	292
30	Gasoline	63	TT	11000	Brockway	Cont.	572
31	Gasoline	71	SU	27000	GMC	Chev.	351
32	Gasoline	61	SU	58900	Mack	Mack	540
33	Gasoline	72	SU	24500	IHC	IHC	345
34	Diesel	65	TT	50000		Cummins	464
35	Gasoline	71	SU	20500	IHC	IHC	304
36	Diesel	65	SU			Cummins	743
37	Diesel	71	SU	41040		Cummins	504
38	Gasoline	72	SU	18500	GMC	Chev.	351
39	Gasoline	65	TT	39700	IHC	IHC	478
42	Diesel	72	TT	60000		D.D.	671
43	Diesel	65	SU	11250		Cummins	855
44	Gasoline	70	SU	10000	Ford	Ford	300
45	Gasoline	61	SU	58900	Mack	Mack	540
47	Diesel		SU			Cummins	
48	Gasoline	60	SU	14000	GMC	Chev.	292
49	Gasoline	73	SU	25500	Ford	Ford	361
50	Gasoline	71	SU	41970	D. Reo	D. Reo	400
51	Gasoline	69	SU	16000	Dodge	Dodge	318
52	Gasoline	67	SU	19500	GMC	Chev.	305
53	Diesel	61	TT	29000		Cummins	672
54	Diesel	71	SU			Cummins	855
55	Diesel	69	TT		GMC	D.D.	568
56	Diesel	72	TT	50500	GMC	D.D.	318
57	Diesel	74	SU			Cummins	855
59	Gasoline	74	SU	44860	IHC	IHC	478
60	Diesel	69	TT	72760		Cummins	855
61	Gasoline	61	SU	58900	Mack	Mack	540
62	Diesel	62	SU	32000		Cummins	672
64	Gasoline	66	TT	68000	IHC	IHC	
65	Diesel	64	TT	50000		Cummins	743

TABLE A-4. DESCRIPTION OF CAPE-21 TRUCKS TESTED IN LOS ANGELES

Truck No.	Fuel	Model Year	Body Type	GVW	Body Mfgr.	Engine Mfgr.	Engine Size
2	Gasoline	70	TT		GMC	GMC	305
3	Gasoline	70	TT	32000	GMC	GMC	351
4	Gasoline	71	SU	16000	Chev.	Chev.	350
5	Gasoline	74	SU	10000	GMC	GMC	250
6	Diesel	74	TT			D. D.	568
7	Gasoline	73	SU	10000	Ford	Ford	390
10	Gasoline	65	SU	10000	Ford	Ford	352
12	Gasoline	66	TT	32000	Ford	Ford	532
13	Gasoline	68	SU	18200	IHC	IHC	265
14	Gasoline		SU	20500	IHC	IHC	304
15	Diesel	63	TT			D. D.	568
17	Gasoline	74	SU	20200	Ford	Ford	330
19	Gasoline	64	SU	23000	Ford	Ford	330
20	Diesel		TT			Cummins	855
21	Propane	73	SU	18060	IHC	IHC	345
22	Diesel		TT			D. D.	568
23	Diesel	74	SU			D. D.	568
24	Gasoline	71	SU	24000	Ford	Ford	361
25	Gasoline	67	SU	21000	GMC	GMC	305
26	Gasoline		SU	22000	IHC	IHC	304
27	Diesel		TT			D. D.	568
28	Gasoline	71	SU	27500	Ford	Ford	391
29	Diesel	73	SU			D. D.	568
30	Gasoline	70	SU	27000	GMC	GMC	351
31	Diesel		SU			Cummins	743
32	Propane	72	SU	16000	Chev.	Chev.	350
33	Diesel		TT			D. D.	568
34	Diesel	73	TT			Cummins	855
35	Gasoline	67	SU	24000	Ford	Ford	391
36	Gasoline	69	SU			Dodge	318
37	Diesel	69	SU			Cummins	855
38	Diesel	69	SU			Cummins	855
39	Gasoline	64	TT	34000	Ford	Ford	534
40	Gasoline		SU	23000	IHC	IHC	345
41	Diesel	71	TT			D. D.	568
42	Gasoline	60	SU	24000	Chev.	Chev.	366
43	Gasoline		TT	35000	IHC	IHC	548
44	Diesel		SU			Cummins	855
45	Diesel	70	TT			D. D.	568
46	Diesel		TT			Cummins	743
47	Gasoline		SU	20500	IHC	IHC	304
48	Gasoline		TT	23000	Ford	Ford	361
51	Diesel	73	TT			D. D.	568

TABLE A-5. DESCRIPTION OF SAN ANTONIO ROAD ROUTE TEST VEHICLES TESTED AFTER JANUARY 1972

Truck No.	Model Year	Make	GVW lbs	Engine CID	Cyl.	Body Style	Date	Mileage	Test Wt.	Trans-mission
1	1971	IHC	16,000	345	V8	Van	1/27/72	9,849	11,945	4-Std
2	1970	Chev.	18,000	350	V8	Van	2/9/72	7,155	13,605	4-Std
3	1972	IHC	19,000	304	V8	Van	2/22/72	474	14,530	5-Std
4B	1970	Ford	10,000	300	I6	Van	3/6/72	19,556	9,740	3-auto
5	1970	Chev.	18,000	350	V8	Van	3/22/72	16,573	13,580	4-Std
6	1972	Ford	24,000	330	V8	Van	4/4/72	10,032	17,645	5-Std
7	1970	GMC	19,500	351	V6	Stake	4/13/72	31,563	14,010	4-Std
8	1972	Ford	27,500	391	V8	Van	4/26/72	40	19,150	5-Std
9	1972	Ford	24,000	330	V8	Van	5/4/72	8,847	17,600	5-Std
10	1972	Ford	19,200	361	V8	Van	5/23/72	6,180	14,870	4-Std
11	1970	Dodge	24,000	318	V8	Van	6/6/72	41,882	17,325	4-Std
12	1972	IHC	22,500	345	V8	Van	6/19/72	7,376	16,430	5-Std
13	1972	IHC	17,000	304	V8	Van	7/7/72	20,417	13,275	4-Std
14	1972	IHC	24,500	345	V8	Van	7/17/72	2,067	17,625	5-Std
15	1970	Ford	10,000	300	I6	Van	7/24/72	26,651	9,590	3-auto
16	1970	Ford	10,000	300	I6	Van	8/3/72	26,428	9,050	3-auto
17	1970	White	30,000	400	I6	Tractor	8/22/72	38,326	21,380	5 Hi-Lo*

---

*Hi-Lo means two speed rear axle

TABLE A-5 (cont'd). DESCRIPTION OF SAN ANTONIO ROAD ROUTE TEST VEHICLES TESTED AFTER JANUARY 1972

Truck No.	Model Year	Make	GVW lbs	Engine CID	Cyl.	Body Style	Date	Mileage	Test Wt.	Trans-mission
18	1971	IHC	32,000	478	V8	Tractor	9/3/72	37,043	23,080	5 Hi-Lo
19	1971	IHC	32,000	478	V8	Tractor	9/12/72	56,956	23,075	5 Hi-Lo
20	1970	White	30,000	400	I6	Tractor	9/18/72	38,496	20,975	5 Hi-Lo
21	1970	GMC	32,500	427	V8	Tractor	9/25/72	71,977	22,290	5 Hi-Lo
22	1971	Chev.	24,000	350	V8	Tractor	10/2/72	30,690	17,165	4-Std
23	1969	Dodge	16,000	316	V8	Van	10/12/72	46,235	12,735	4-Std
24	1970	Chev.	32,000	366	V8	Stake	10/20/72	5,207	20,880	5-Std
25	1970	Dodge	24,000	318	V8	Van	11/27/72	37,000	17,065	4-Std

TABLE A-6. DESCRIPTION OF PRECONTROLLED GASOLINE POWERED TRUCKS TESTED ON THE SAN ANTONIO ROAD ROUTE

Truck No.	Model Year	Make	GVW lbs	Weight-lbs	Empty Wt.	Engine CID	Cyl.	Body Style	Trans-mission	Mileage
G-1	1967	Ford	17,000	12,400	7,800	330	V8	Van	4-Std	84,256
G-2	1968	IHC	18,200	14,900	11,600	304	V8	Van	4-Std	69,156
G-3	1967	Ford	10,000	9,140	8,280	300	I6	Van	Auto	57,686
G-4	1969	Chevy	18,000	13,475	8,950	350	V8	Van	4-Std	38,795
G-5	1967	Dodge	19,500	13,875	8,250	318	V8	Stake	5 Hi-Lo*	39,005
G-6	1968	IHC	27,500	18,960	10,420	345	V8	Dump	5 Hi-Lo*	56,461
G-7	1965	Chevy	19,500	14,850	10,200	292	I6	Van	4-Std	46,486
G-8	1965	GMC	19,500	15,970	12,440	351	V6	Van	5 Hi-Lo*	94,552
G-9	1966	Chevy	34,400**	22,650	11,300	366	V9	Tractor	4 Hi-Lo*	30,471
G-10	1969	Ford	43,500**	28,900	14,300	391	V8	Tractor	5 Hi-Lo*	71,581

---

* Hi-Lo means two speed rear axle

**Gross Combined Weight

TABLE A-7. DESCRIPTION OF DIESEL TRUCKS OPERATED OVER SAN ANTONIO ROAD ROUTE

Truck No.	Model Year	Chassis Mfgr.	Engine Mfgr.	Engine Model	Engine CID	Cyl.	Type Aspiration	Trans-mission	Body Style	GVW or GCW	Test Weight	Mileage
D-1	1972	Ford	Caterpillar	1150	573	V8	Natural	5 spd	Van	24,000	18,820	33,075
D-2	1970	IH	Cummins	V903	903	V8	Natural	15 spd	Tractor	58,000	42,800	295,262
D-3	1971	IH	Det. Diesel	6-71	426	I6	Normal	10 spd	Tractor	58,000	41,500	182,320
D-4	1970	White	Cummins	NHC-250	855	I6	Natural	10 spd	Tractor	58,000	39,490	99,533
D-5	1973	IH	Caterpillar	1160	636	V8	Natural	5 spd	Tractor	58,000	37,610	8,741
D-6	1973	Mack	Mack	ENDT 676B	672	I6	Turbocharged	10 spd	Tractor	72,000	49,460	12,545
D-7	1973	Mack	Det. Diesel	8V-71	568	V8	Normal	10 spd	Tractor	72,000	50,580	12,499
D-8	1970	Mack	Mack	ENDT 673B	672	I6	Turbocharged	10 spd	Tractor	58,000	41,090	294,010
D-9	1973	Mack	Cummins	NTC-290	855	I6	Turbocharged	10 spd	Tractor	72,000	50,980	17,487
D-10	1970	Ford	Det. Diesel	4L-53	212	I4	Normal	5 spd	Van	17,000	14,430	119,775

TABLE A-8. FORTRAN LISTING OF PROGRAM TO CALCULATE NEW MODAL WEIGHTING FACTORS

```
      PROGRAM LINPRG(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C REMARKS
C SINCE THIS PROGRAM IS COMPLETE IN ALL RESPECTS,IT CAN BE
C RUN AS IT IS WITHOUT ANY ADDITIONAL MODIFICATION OR
C INSTRUCTION.IN SUCH CASE FOLLOW THE INPUT FORMAT AS GIVEN
C
C PROGRAM FOR SOLVING LINEAR AND QUADRATIC PROGRAMMING
C PROBLEMS IN THE FORM W=M*Z+Q, W.Z=0, W AND Z NONNEGATIVE
C BY LEMKE/S ALGORITHM.
C
C MAIN PROGRAM WHICH CALLS THE SIX SUBROUTINES-MATRIX,
C INITIA,NEWBAS,SORT,PIVOT AND PPRINT IN PROPER ORDER.
C
      COMMON AM,Q,L1,B,NL1,NL2,A,NE1,NE2,IR,MBASIS,W,Z,IZR,M,X,Y,K,DESC
      DIMENSION AM(50,50), Q(50), B(50,50), A(50)
      DIMENSION W(50), Z(50), MBASIS(100),X(50,20),Y(50),XX(20,20)
      INTEGER DESC(18)
C DESCRIPTION OF PARAMETERS IN COMMON
C   AM       A TWO DIMENSIONAL ARRAY CONTAINING THE
C            ELEMENTS OF MATRIX M.
C   Q        A SINGLY SUBSCRIPTED ARRAY CONTAINING THE
C            ELEMENTS OF VECTOR Q.
C   L1       AN INTEGER VARIABLE INDICATING THE NUMBER OF
C            ITERATIONS TAKEN FOR EACH PROBLEM.
C   B        A TWO DIMENSIONAL ARRAY CONTAINING THE
C            ELEMENTS OF THE INVERSE OF THE CURRENT BASIS.
C   W        A SINGLY SUBSCRIPTED ARRAY CONTAINING THE VALUES
C            OF W VARIABLES IN EACH SOLUTION.
C   Z        A SINGLY SUBSCRIPTED ARRAY CONTAINING THE VALUES
C            OF Z VARIABLES IN EACH SOLUTION.
C   NL1      AN INTEGER VARIABLE TAKING VALUE 1 OR 2 DEPEND-
C            ING ON WHETHER VARIABLE W OR Z LEAVES THE BASIS
C   NE1      SIMILAR TO NL1 BUT INDICATES VARIABLE ENTERING
C   NL2      AN INTEGER VARIABLE INDICATING WHAT COMPONENT
C            OF W OR Z VARIABLE LEAVES THE BASIS.
C   NE2      SIMILAR TO NL2 BUT INDICATES VARIABLE ENTERING
C   A        A SINGLY SUBSCRIPTED ARRAY CONTAINING THE
C            ELEMENTS OF THE TRANSFORMED COLUMN THAT IS
C            ENTERING THE BASIS.
C   IR       AN INTEGER VARIABLE DENOTING THE PIVOT ROW AT
C            EACH ITERATION. ALSO USED TO INDICATE TERMINA-
C            TION OF A PROBLEM BY GIVING IT A VALUE OF 1000.
C   MBASIS   A SINGLY SUBSCRIPTED ARRAY-INDICATOR FOR THE
C            BASIC VARIABLES. TWO INDICATORS ARE USED FOR
C            EACH BASIC VARIABLE-ONE INDICATING WHETHER
C            IT IS A W OR Z AND ANOTHER INDICATING WHAT
C            COMPONENT OF W OR Z.
C
```

TABLE A-8 (cont'd). FORTRAN LISTING OF PROGRAM TO CALCULATE NEW MODAL WEIGHTING FACTORS

```
C READ IN THE VALUE OF VARIABLE IP INDICATING THE
C NUMBER OF PROBLEMS TO BE SOLVED.
      READ(5,3) IP
C
C READ IN THE VALUES FOR K AND M
C
      READ (5,40) K,M
   40 FORMAT (I2,3X,I2)
C
C READ THE ELEMENTS OF THE X MATRIX CASE BY CASE
C
       DO 20 J=1,K
   20 READ (5,30) (X(I,J),I=1,M)
   30 FORMAT (11(32X,F6.0/)32X,F6.0)
C
C CALCULATE XTX MATRIX (KXK)
C
      DO 10 I=1,K
      DO 10 J=I,K
      XX(I,J)=0.0
      DO 18 JJ=1,M
   18 XX(I,J)=XX(I,J)+X(JJ,I)*X(JJ,J)
   10 XX(J,I)=XX(I,J)
C
C DERIVE AM MATRIX ((2K+2)X(2K+2))
C
      DO 13 I=1,K
      DO 13 J=1,K
   13 AM(I,J)=2.0*XX(I,J)
      K1=K+1
      K2=2*K+2
      K3=2*K+1
      DO 15 I=1,K
      DO 15 J=K1,K2
      AM(I,J)=0.0
   15 AM(J,I)=0.0
      DO 14 I=1,K
      I1=K+I
      AM(I,I1)=1.0
      AM(I1,I)=-1.0
      AM(K3,I)=-1.0
      AM(K2,I)=1.0
      AM(I,K3)=1.0
   14 AM(I,K2)=-1.0
      DO 16 I=K1,K2
      DO 16 J=K1,K2
   16 AM(I,J)=0.0
C
C VARIABLE NO INDICATES THE CURRENT PROBLEM BEING SOLVED
      NO=0
    1 NO=NO+1
      IF (NO.GT.IP) GO TO 5
      WRITE(6,2) NO
    2 FORMAT (1H1,10X,11HPROBLEM NO.,I2)
```

TABLE A-8 (cont'd). FORTRAN LISTING OF PROGRAM TO CALCULATE NEW MODAL WEIGHTING FACTORS

```
C READ IN THE SIZE OF THE MATRIX M
      READ(5,3) N
    3 FORMAT (I2)
C PROGRAM CALLING SEQUENCE
      CALL MATRIX (N)
C PARAMETER N INDICATES THE PROBLEM SIZE
      CALL INITIA (N)
C SINCE FOR ANY PROBLEM TERMINATION CAN OCCUR IN INITIA,
C NEWBAS OR SORT SUBROUTINE,THE VALUE OF IR IS MATCHED WITH
C 1000 TO CHECK WHETHER TO CONTINUE OR GO TO NEXT PROBLEM.
      IF (IR.EQ.1000) GO TO 1
    4 CALL NEWBAS (N)
      IF (IR.EQ.1000) GO TO 1
      CALL SORT (N)
      IF (IR.EQ.1000) GO TO 1
      CALL PIVOT (N)
      GO TO 4
    5 STOP
      END
      SUBROUTINE MATRIX (N)
C PURPOSE - TO INITIALIZE AND READ IN THE VARIOUS INPUT DATA
C
      COMMON AM,Q,L1,R,NL1,NL2,A,NE1,NE2,IR,MBASIS,W,Z,IZR,M,X,Y,K,DESC
      DIMENSION AM(50,50), Q(50), B(50,50), A(50)
      DIMENSION W(50), Z(50), MBASIS(100)
      DIMENSION X(50,20),Y(50),XX(20,20),XY(20)
      INTEGER DESC(16),FMT(16)
C
C K SHOULD NOT BE LARGER THAN 20, AND M,50. IFMT=1,2   AND IDESC=1,2
C
       READ (5,50)      IFMT,IDESC
   50 FORMAT(I2,3X,I2)
      KDESC=IDESC*8
      KFMT=IFMT*8
       READ (5,12) (DESC(I),I=1,KDESC)
       READ (5,12) (FMT(I),I=1,KFMT)
   12 FORMAT(8A10)
       WRITE (6,51) (DESC(I),I=1,KDESC)
      WRITE (6,52) (FMT(I),I=1,KFMT)
   52 FORMAT(* *,*INPUT FORMAT = *,(8A10/))
   51 FORMAT(* *,(8A10/))
C
C READ THE ELEMENTS OF THE Y VECTOR CASE BY CASE
C
      READ (5,FMT) (Y(I),I=1,12)
C
C CALCULATE X'Y MATRIX (XY1)
C
      DO 11 I=1,K
      XY(I)=0.0
      DO 11 J=1,M
   11 XY(I)=XY(I)+Y(J)*X(J,I)
C
```

TABLE A-8 (cont'd). FORTRAN LISTING OF PROGRAM TO CALCULATE
NEW MODAL WEIGHTING FACTORS

```
C CALCULATE THE ELEMENTS OF THE Q VECTOR
C
      K2=2*K+2
      K3=2*K+1
      DO 17 I=1,K
      Q(I)=-2.0*XY(I)
      J=I+K
   17 Q(J)=1.0
      Q(K3)=1.0
      Q(K2)=-.999998
C IN ITERATION 1,BASIS INVERSE IS AN IDENTITY MATRIX.
      DO 5 J=1,N
        DO 4 I=1,N
          IF (I.EQ.J) GO TO 3
          B(I,J)=0.0
          GO TO 4
    3     B(I,J)=1.0
    4     CONTINUE
    5   CONTINUE
      RETURN
      END
      SUBROUTINE INITIA (N)
C PURPOSE-TO FIND THE INITIAL ALMOST COMPLEMENTARY SOLUTION
C         BY ADDING AN ARTIFICIAL VARIABLE Z0.
C
      COMMON AM,Q,L1,B,NL1,NL2,A,NE1,NE2,IR,MBASIS,W,Z,IZR,M,X,Y,K,DESC
      DIMENSION AM(50,50), Q(50), B(50,50), A(50)
      DIMENSION W(50), Z(50), MBASIS(100),X(50,20),Y(50),XX(20,20)
      INTEGER DESC(18)
C SET Z0 EQUAL TO THE MOST NEGATIVE Q(I)
      I=1
      J=2
    1 IF (Q(I).LE.Q(J)) GO TO 2
      I=J
    2 J=J+1
      IF (J.LE.N) GO TO 1
C UPDATE W VECTOR
      IR=I
      T1=-Q(IR)
      IF (T1.LE.0.0) GO TO 4
      DO 3 I=1,N
        W(I)=Q(I)+T1
    3   CONTINUE
      Q(IR)=T1
C UPDATE BASIS INVERSE AND INDICATOR VECTOR
C OF BASIC VARIABLES.
      DO 4 J=1,N
      B(J,IR) =-1.0
        W(J)=Q(J)
        Z(J)=0.0
        MBASIS(J)=1
        L=N+J
        MBASIS(L)=J
    4   CONTINUE
```

TABLE A-8 (cont'd). FORTRAN LISTING OF PROGRAM TO CALCULATE NEW MODAL WEIGHTING FACTORS

```
      IZR=IR
      NL1=1
      L=N+IR
      NL2=IR
      MBASIS(IR)=3
      MBASIS(L)=0
      W(IR)=0.0
      Z0=Q(IR)
      I1=1
C PRINT THE INITIAL ALMOST COMPLEMENTARY SOLUTION
      WRITE(6,5)
    5 FORMAT (3(/),5X,29HINITIAL ALMOST COMPLEMENTARY ,
     1    8HSOLUTION)
      DO 7 I=1,N
        WRITE(6,6) I,W(I)
    6   FORMAT (10X,2HW(,I4,2H)=,F15.5)
    7   CONTINUE
      WRITE(6,8) Z0
    8 FORMAT (10X,3HZ0=,F15.5)
      RETURN
    9 WRITE (6,10)
   10 FORMAT (5X,36HPROBLEM HAS A TRIVIAL COMPLEMENTARY ,
     1    23HSOLUTION WITH W=Q, Z=0.)
      IR=1000
      RETURN
      END
      SUBROUTINE NEWBAS (N)
C PURPOSE - TO FIND THE NEW BASIS COLUMN TO ENTER IN
C             TERMS OF THE CURRENT BASIS.
C
      COMMON AM,Q,I1,B,NL1,NL2,A,NE1,NE2,IR,MBASIS,W,Z,IZR,M,X,Y,K,DESC
      DIMENSION AM(50,50), Q(50), B(50,50), A(50)
      DIMENSION W(50), Z(50), MBASIS(100),X(50,20),Y(50),XX(20,20)
      INTEGER DESC(16)
C IF NL1 IS NEITHER 1 NOR 2 THEN THE VARIABLE Z0 LEAVES THE
C BASIS INDICATING TERMINATION WITH A COMPLEMENTARY SOLUTION
      IF (NL1.EQ.1) GO TO 2
      IF (NL1.EQ.2) GO TO 5
      WRITE(6,1)
    1 FORMAT (5X,22HCOMPLEMENTARY SOLUTION)
      CALL PPRINT (N)
      IR=1000
      RETURN
    2 NE1=2
      NE2=NL2
C UPDATE NEW BASIC COLUMN BY MULTIPLYING BY BASIS INVERSE.
      DO 4 I=1,N
        T1=0.0
        DO 3 J=1,N
    3     T1=T1-B(I,J)*AM(J,NE2)
        A(I)=T1
    4   CONTINUE
      RETURN
```

TABLE A-8 (cont'd). FORTRAN LISTING OF PROGRAM TO CALCULATE NEW MODAL WEIGHTING FACTORS

```
    5 NE1=1
      NE2=NL2
      DO 6 I=1,N
        A(I)=B(I,NE2)
    6   CONTINUE
      RETURN
      END
      SUBROUTINE SORT (N)
C PURPOSE - TO FIND THE PIVOT ROW FOR NEXT ITERATION BY THE
C            USE OF (SIMPLEX-TYPE) MINIMUM RATIO RULE.
C
C IN ANY ACTUAL IMPLEMENTATION NB SHOULD BE RE-
C PLACED BY B-11 WHERE B IS THE NUMBER OF BITS IN
C THE FLOATING POINT MANTISSA AS CLASEN SUGGESTS IN
C COMM. ACM, VOL.9 (1966),802-3.
      COMMON AM,Q,L1,B,NL1,NL2,A,NE1,NE2,IR,MBASIS,W,Z,IZR,M,X,Y,K,DESC
      DIMENSION AM(50,50), Q(50), B(50,50), A(50)
      DIMENSION W(50), Z(50), MBASIS(100),X(50,20),Y(50),XX(20,20)
      INTEGER DESC(16)
      AMAX=ABS(A(1))
      DO 10 I=2,N
      IF(AMAX.GE.ABS(A(I)))GO TO 10
      AMAX=ABS(A(I))
   10 CONTINUE
      TOL=AMAX*2.0**(-37)
      I=1
    1 IF (A(I).GT.0.0) GO TO 2
      I=I+1
      IF(I.GT.N)GO TO 9
      GO TO 1
    2 T1=Q(I)/A(I)
      IR=I
    3 I=I+1
      IF (I.GT.N) GO TO 5
      IF (A(I).GT.0.0) GO TO 4
      GO TO 3
    4 T2=Q(I)/A(I)
      IF (T2.GE.T1) GO TO 3
      IR=I
      T1=T2
      GO TO 3
    5 RETURN
C FAILURE OF THE RATIO RULE INDICATES TERMINATION WITH
C NO COMPLEMENTARY SOLUTION.
    6 WRITE(6,7)
    7 FORMAT (5X,37HPROBLEM HAS NO COMPLEMENTARY SOLUTION)
      WRITE(6,8) L1
    8 FORMAT (10X,13HITERATION NO.,I4)
      IR=1000
      RETURN
    9 IF(Q(IZR).GT.TOL)GO TO 6
      WRITE(6,11)
   11 FORMAT(5X,22HCOMPLEMENTARY SOLUTION)
      CALL PPRINT(N)
      IR=1000
      RETURN
      END
```

TABLE A-8 (cont'd). FORTRAN LISTING OF PROGRAM TO CALCULATE NEW MODAL WEIGHTING FACTORS

```
      SUBROUTINE PIVOT (N)
C PURPOSE - TO PERFORM THE PIVOT OPERATION BY UPDATING THE
C             INVERSE OF THE BASIS AND Q VECTOR.
C
      COMMON AM,Q,L1,B,NL1,NL2,A,NE1,NE2,IR,MBASIS,W,Z,IZR,M,X,Y,K,DESC
      DIMENSION AM(50,50), Q(50), B(50,50), A(50)
      DIMENSION W(50), Z(50), MBASIS(100),X(50,20),Y(50),XX(20,20)
      INTEGER DESC(16)
      DO 1 I=1,N
    1   B(IR,I)=B(IR,I)/A(IR)
      Q(IR)=Q(IR)/A(IR)
      DO 3 I=1,N
        IF (I.EQ.IR) GO TO 3
        Q(I)=Q(I)-Q(IR)*A(I)
        DO 2 J=1,N
          B(I,J)=B(I,J)-B(IR,J)*A(I)
    2     CONTINUE
    3   CONTINUE
C UPDATE THE INDICATOR VECTOR OF BASIC VARIABLES
      NL1=MBASIS(IR)
      L=N+IR
      NL2=MBASIS(L)
      MBASIS(IR)=NE1
      MBASIS(L)=NE2
      L1=L1+1
      RETURN
      END
      SUBROUTINE PPRINT (N)
C PURPOSE - TO PRINT THE CURRENT SOLUTION TO COMPLEMENTARY
C             PROBLEM AND THE ITERATION NUMBER.
C
      COMMON AM,Q,L1,B,NL1,NL2,A,NE1,NE2,IR,MBASIS,W,Z,IZR,M,X,Y,K,DESC
      DIMENSION AM(50,50),Q(50),B(50,50),A(50),X(50,20),Y(50)
      DIMENSION W(50),Z(50),MBASIS(100),SUM(50),RES(50),XX(20,20),BB(12)
      INTEGER DESC(16)
      WRITE(6,1) L1
    1 FORMAT (10X,13HITERATION NO.,I4)
      I=N+1
      J=1
      DO 10 JJ=1,M
       BB(JJ)=0.
   10 SUM(JJ)=0.
    2 K1=MBASIS(I)
      K2=MBASIS(J)
      IF (Q(J).GT.0.0) GO TO 3
      Q(J)=0.0
    3 IF (K2.EQ.1) GO TO 5
      WRITE(6,4) K1,Q(J)
    4 FORMAT (10X,2HZ(,I4,2H)=,F15.5)
       BB(K1)=Q(J)
      IF (K1.GT.11) GO TO 7
      DO 8 JJ=1,M
    8 SUM(JJ)=SUM(JJ)+Q(J )*X(JJ,K1)
```

TABLE A-8 (cont'd). FORTRAN LISTING OF PROGRAM TO CALCULATE NEW MODAL WEIGHTING FACTORS

```
      GO TO 7
    5 WRITE(6,6) KI,W(J)
    6 FORMAT (10X,2HW(,I4,2H)=,F15.5)
    7 I=I+1
      J=J+1
      IF (J.LE.N) GO TO 2
      RS=0.0
      YY=0.0
      PRINT50
   50 FORMAT(*1*)
       WRITE (6,51) (DESC(I),I=1,8)
   51 FORMAT(* *,(8A10/))
       WRITE (6,60)
   60 FORMAT (////,50X,*REGRESSION COEFFICIENTS*)
       WRITE (6,61)
   61 FORMAT (12X,*IDLE*,11X,*MODE 2*,9X,*MODE 3*,9X,*MODE 4*,9X,*MODE 5
     1*,9X,*MODE 6*)
      WRITE (6,62) (BB(J),J=1,6)
   62 FORMAT ( 9X,6F15.6)
      WRITE (6,60)
      WRITE (6,67)
   67 FORMAT (12X,*MODE 8*,9X,*MODE 9*,9X,*MODE 10*,8X,*MODE 11*,8X,*MOD
     1E 12*)
      WRITE (6,62) (BB(J),J=7,11)
      WRITE(6,68)
   68 FORMAT(////)
      WRITE (6,12)
   12 FORMAT (/,2X,*CASE NO.*,3X,*PREDICTED Y*,5X,*OBSERVED Y*,7X,*RESID
     1UAL*,7X,* IDLE *,9X,*MODE 2*,9X,*MODE 3*,9X,*MODE 4*,9X,*MODE 5*)
      DO 11 JJ=1,M
      YY=YY+Y(JJ)*Y(JJ)
       RES(JJ)=Y(JJ)-SUM(JJ)
      WRITE (6,13) JJ,SUM(JJ),Y(JJ),RES(JJ),X(JJ,1),X(JJ,2),X(JJ,3),
     1X(JJ,4),X(JJ,5)
   13 FORMAT (4X,I2,3X,8F15.5)
   11 RS=RS+RES(JJ)*RES(JJ)
      WRITE (6,17)
   17 FORMAT(/,2X,*CASE NO.*,36X,*MODE 6*,9X,*MODE 8*,9X,*MODE 9*,9X,*MO
     1DE 10*,8X,*MODE 11*,8X,*MODE 12*)
       DO 20 JJ =1,M
   20 WRITE (6,18) JJ,X(JJ,6),X(JJ,7),X(JJ,8),X(JJ,9),X(JJ,10),X(JJ,11)
   18 FORMAT (4X,I2,33X,7F15.5)
      WRITE (6,19) RS
   19 FORMAT (/,10X,*RESIDUAL SUM OF SQUARES =*,F15.6)
      SIGMA=SQRT(RS)
      WRITE(6,21)SIGMA
   21 FORMAT(26X,*SIGMA =*,F15.6)
      R2=1.-RS/YY
      R=SQRT(R2)
      WRITE (6,15) R
   15 FORMAT (10X,25HCORRELATION COEFFICIENT =,F15.6)
      WRITE (6,16) R2
   16 FORMAT (10X,30HCOEFFICIENT OF DETERMINATION =,F10.6)
      RETURN
      END
```

TABLE A-9. DESCRIPTION OF STEADY STATE AND SINUSOIDAL TEST CYCLES FOR ALL TRUCKS TESTED UNDER CONTRACT 68-03-2147

Steady State Cycles

Cycle Designation	Speed kph	Description	Cycle length seconds
00SS	0	operation at idle	120
05SS	8	operation at constant 8 kph	120
10SS	16	operation at constant 16 kph	120
15SS	24	operation at constant 24 kph	120
20SS	32	operation at constant 32 kph	120
30SS	48	operation at constant 48 kph	120
40SS	64	operation at constant 64 kph	120
55SS	89	operation at constant 89 kph*	120

Sinusoidal Cycles

Cycle Designation	Avg Speed kph	Speed Variation kph (ΔV)	Description
20 ± 5	32	± 8.0	sinusoidal speed time relationship, ± 8.0 or (3.2) kph about average speed with frequency determined by time for WOT accel from -ΔV to + ΔV for each truck
30 ± 5	48	± 8.0	
40 ± 2	64	± 3.2	

---

* or max speed if vehicle could not reach 89 kph

TABLE A-10. DESCRIPTION OF CHASSIS DYNAMOMETER TRANSIENT DRIVING CYCLES

Vehicle		Cycle	EPA Cycle	Duration,	Avg. Speed,
No.	Desc.	Desc.	Number	seconds	km/hr
1-8, 17	D2GAS	05	180622075	576	8.50
		10	925077131	580	16.53
		15	1874219417	603	24.67
		20	1638863867	637	33.63
17 Alt.	D2GAS Alternate	05	1162034257	651	7.65
		10	334486913	500	15.86
		15	2012212305	611	24.23
		20	1674619155	601	33.30
09, 11, 15, 16	D3GAS	05	1245377313	714	8.24
		10	532860011	623	16.11
		15	1566793097	644	24.01
		20	400624235	736	31.78
10, 12 13, 14 18	TTGAS	05	1031942939	777	8.23
		10	2058474153	656	16.79
		15	2109872435	727	24.01
		20	380668241	753	32.78
18 Alt.	TTGAS Alternate	05	310823643	699	7.85
		10	1718373307	676	16.65
		15	1204338883	786	23.67
		20	1188064411	745	31.39
19, 29	D2DIE	05	390741665	652	8.91
		10	1527266763	675	15.56
		15	113778723	779	23.51
		20	555005187	772	33.17
28, 30	D3DIE	05	882238513	791	8.04
		10	202042971	761	15.65
		15	743630625	641	24.09
		20	1200794289	734	31.82
20-27	TTDIE	05	767793819	827	8.22
		10	802433547	776	16.50
		15	605752003	697	24.00
		20	462050771	669	31.32
24 Alt.	TTDIE Alternate # 1	05	1624531969	824	7.63
		10	2112632739	782	16.49
		15	201419497	749	24.75
		20	999014859	668	31.34
25 Alt.	TTDIE Alternate # 2	05	1640346049	829	8.62
		10	1143551683	775	15.83
		15	1790747657	708	24.33
		20	51384161	749	31.52

APPENDIX B

DATA IN SUPPORT OF GASOLINE TRUCK DATA ANALYSIS

TABLE B-1. COMPARISON OF CYCLE-TO-CYCLE AND TEST-TO-TEST VARIABILITY FOR HC FROM GASOLINE TRUCK TESTS

Average Speed	Empty Load		Half Load		Full Load		N
	Var.(a)	Sig.(b)	Var.	Sig.	Var.	Sig.	
Cycle-to-Cycle							
8 kph	0.65	*	0.69	*	1.02	**	4
16 kph	3.12	***	3.32	**	4.52	**	4
24 kph	3.53	***	4.02	**	4.77	**	4
32 kph	2.92	***	6.33	***	12.28	***	6
48 kph	0.08	n.s.	1.62	**	12.08	**	4
64 kph	<0.01	n.s.	0.03	n.s.	<0.01	n.s.	4
all steady state	<0.01	n.s.	0.10	***	0.23	***	12
all sinusoidal	2.71	n.s.	6.59	n.s.	15.05	***	6
all driving	0.60	n.s.	0.67	***	0.73	***	8
Test-to-Test							
8 kph	0	n.s.	0	n.s.	0	n.s.	4
16 kph	<0.01	n.s.	0	n.s.	0	n.s.	4
24 kph	<0.01	n.s.	<0.01	n.s.	0	n.s.	4
32 kph	0	n.s.	0.08	n.s.	0.01	n.s.	6
48 kph	0	n.s.	0	n.s.	0	n.s.	4
64 kph	0	n.s.	0	n.s.	0	n.s.	4
all steady state	0	n.s.	0	n.s.	<0.01	n.s.	12
all sinusoidal	0	n.s.	0	n.s.	0	n.s.	6
all driving	<0.01	n.s.	0.25	*	0.05	n.s.	8

(a) Variability: cycle-to-cycle = (MSC-MSE)/N
test-to-test = (MSR(T)-MSE)/2

(b) Significance: * = 0.05
** = 0.01
*** = 0.001
n.s. = not significant

Note 1: Where possible, as determined by significance of F ratio from truck by cycle interaction, the pooled MSE was used in the calculations.

2: Values of "0" reflect negative estimates.

3: MSC - mean square cycle value
MSE - mean square error
MSR(T) - mean square repeat value within each truck
N - sample size

TABLE B-2. COMPARISON OF CYCLE-TO-CYCLE AND TEST-TO-TEST VARIABILITY FOR CO FROM GASOLINE TRUCK TESTS

Average Speed	Empty Load		Half Load		Full Load		N
	Var.(a)	Sig.(b)	Var.	Sig.	Var.	Sig.	
Cycle-to-Cycle							
8 kph	33.29	**	36.41	**	140.84	**	4
16 kph	317.87	***	486.44	**	1080.77	***	4
24 kph	516.75	*	835.10	***	1707.08	***	4
32 kph	639.12	***	817.63	**	1462.50	***	6
48 kph	11.69	**	33.39	*	1201.10	***	4
64 kph	1.30	*	0.98	n.s.	19.04	**	4
all steady state	40.58	n.s.	939.67	***	3238.76	***	12
all sinusoidal	0.02	n.s.	0	n.s.	575.16	**	6
all driving	284.63	***	447.05	***	625.56	***	8
Test-to-Test							
8 kph	0	n.s.	0.13	n.s.	0	n.s.	4
16 kph	0	n.s.	2.33	n.s.	0	n.s.	4
24 kph	0	n.s.	0.27	n.s.	0	n.s.	4
32 kph	0	n.s.	0	n.s.	19.10	n.s.	6
48 kph	0.39	n.s.	0.14	n.s.	0	n.s.	4
64 kph	0.20	n.s.	0	n.s.	1.42	n.s.	4
all steady state	0	n.s.	0	n.s.	0	n.s.	12
all sinusoidal	0.40	n.s.	0	n.s.	17.07	n.s.	6
all driving	0	n.s.	5.31	n.s.	6.72	n.s.	8

(a) Variability: cycle-to-cycle = (MSC-MSE)/N
test-to-test = (MSR(T)-MSE)/2

(b) Significance: * = 0.05
** = 0.01
*** = 0.001
n.s. = not significant

Note 1: Where possible, as determined by significance of F ratio from truck by cycle interaction, the pooled MSE was used in the calculations.

2: Values of "0" reflect negative estimates.

3: MSC - mean square cycle value
MSE - mean square error
MSR(T) - mean square repeat value within each truck
N - sample size

TABLE B-3. COMPARISON OF CYCLE-TO-CYCLE AND TEST-TO-TEST VARIABILITY FOR NO_x FROM GASOLINE TRUCK TESTS

Average Speed	Empty Load		Half Load		Full Load		N
	Var.[(a)]	Sig.[(b)]	Var.	Sig.	Var.	Sig.	
			Cycle-to-Cycle				
8 kph	<0.01	n.s.	0	n.s.	0.02	*	4
16 kph	0.19	*	0.18	*	0.38	*	4
24 kph	0.58	***	0.50	*	0.91	**	4
32 kph	0.67	***	0.97	***	0.97	***	6
48 kph	0.57	*	2.19	**	0.50	*	4
64 kph	0	n.s.	<0.01	n.s.	0	n.s.	4
all steady state	8.89	***	11.32	***	6.18	***	12
all sinusoidal	2.60	***	4.55	***	12.06	***	6
all driving	0.75	***	0.87	***	0.86	***	8
			Test-to-Test				
8 kph	0	n.s.	0	n.s.	0	n.s.	4
16 kph	0	n.s.	0	n.s.	0	n.s.	4
24 kph	0.02	**	0	n.s.	<0.01	n.s.	4
32 kph	0.01	n.s.	0.03	n.s.	0	n.s.	6
48 kph	0	n.s.	0	n.s.	0	n.s.	4
64 kph	0	n.s.	0	n.s.	0	n.s.	4
all steady state	0	n.s.	0.05	n.s.	0	n.s.	12
all sinusoidal	0.12	*	0.08	n.s.	0	n.s.	6
all driving	0.02	*	0.02	n.s.	0.01	n.s.	8

(a) Variability: cycle-to-cycle = (MSC-MSE)/N
test-to-test = (MSR(T)-MSE)/2

(b) Significance: * = 0.05
** = 0.01
*** = 0.001
n.s. = not significant

Note 1: Where possible, as determined by significance of F ratio from truck by cycle interaction, the pooled MSE was used in the calculations.
2: Values of "0" reflect negative estimates.
3: MSC - mean square cycle value
MSE - mean square error
MSR(T) - mean square repeat value within each truck
N - sample size

TABLE B-4. COMPARISON OF CYCLE-TO-CYCLE AND TEST-TO-TEST VARIABILITY FOR FUEL RATE FROM GASOLINE TRUCK TESTS

Average Speed	Empty Load		Half Load		Full Load		N
	Var.[a]	Sig.[b]	Var.	Sig.	Var.	Sig.	
			Cycle-to-Cycle				
8 kph	1672.09	*	1426.91	**	941.98	***	4
16 kph	558.39	**	271.23	*	25.00	n.s.	4
24 kph	0	n.s.	0	n.s.	256.85	*	4
32 kph	297.71	**	423.82	**	372.83	**	6
48 kph	0	n.s.	1.65	n.s.	262.93	**	4
64 kph	2.93	n.s.	6.23	n.s.	13.90	n.s.	4
all steady state	5805.38	***	9003.37	***	11871.92	***	12
all sinusoidal	3620.34	***	3731.88	***	2824.97	***	6
all driving	2402.26	***	3168.29	***	3484.37	***	8
			Test-to-Test				
8 kph	0	n.s.	8.12	n.s.	17.42	*	4
16 kph	10.69	n.s.	50.42	n.s.	17.18	n.s.	4
24 kph	0	n.s.	0	n.s.	1.19	n.s.	4
32 kph	5.12	n.s.	0	n.s.	0	n.s.	6
48 kph	0	n.s.	10.63	n.s.	6.54	n.s.	4
64 kph	0	n.s.	0	n.s.	0	n.s.	4
all steady state	164.89	*	28.38	n.s.	74.15	n.s.	12
all sinusoidal	79.33	*	0	n.s.	17.40	n.s.	6
all driving	0	n.s.	9.09	n.s.	0	n.s.	8

---

[a] Variability: cycle-to-cycle = (MSC-MSE)/N
test-to-test = (MSR(T)-MSE)/2

[b] Significance: * = 0.5
** = 0.1
*** = 0.001
n.s. = not significant

Note 1: Where possible, as determined by significance of F ratio from truck by cycle interaction, the pooled MSE was used in the calculations.

2: Values of "0" reflect negative estimates.

3: MSC - mean square cycle value
MSE - mean square error
MSR(T) - mean square repeat value within each truck
N - sample size

TABLE B-5. COEFFICIENTS FOR STEPWISE MULTIPLE REGRESSION ANALYSIS
TEST CYCLE HC EMISSIONS AS A FUNCTION OF MODAL HC EMISSIONS FOR NINE GASOLINE TRUCKS

Chassis Cycle	16" Coeff.	16" Entered	Idle Coeff.	Idle Entered	10" Coeff.	10" Entered	19" Coeff.	19" Entered	3" Coeff.	3" Entered	CT Coeff.	CT Entered	r^2
Empty Load													
Driving													
5			1.0954	1									0.994
10			1.0169	1							0.1093	2	0.989
15			0.8144	1							0.0824	2	0.982
20			0.8394	1							0.1118	2	0.978
Sinusoidal													
20			0.6486	2							0.3253	1	0.968
30			0.4654	2					0.3922	1		1	0.974
Half Load													
Driving													
5			1.0145	1									0.978
10			0.9797	1							0.1325	2	0.970
15			0.8189	1							0.0971	2	0.980
20			0.8288	1							0.1535	2	0.966
Sinusoidal													
20											0.5537	1	0.944
30			0.6694								0.2595	1	0.975
Full Load													
Driving													
5			1.0906	1									0.986
10			1.3113	1							0.1538	2	0.980
15			0.9705	1							0.1165	2	0.989
20			1.0650	1							0.1860	2	0.980
Sinusoidal													
20			0.9756	2							0.4635	1	0.956
30			0.7160	2							0.3457	1	0.977

Note: Variables entered to 0.05 significance level

TABLE B-6. COEFFICIENTS FOR STEPWISE MULTIPLE REGRESSION ANALYSIS
TEST CYCLE CO EMISSIONS AS A FUNCTION OF MODAL CO EMISSIONS FOR NINE GASOLINE TRUCKS

Chassis	16"		Idle		10"		19"		3"		CT		
Cycle	Coeff.	Entered	Coeff.	Entered	Coeff.	Entered	Coeff.	Entered	Coeff.	Entered	Coeff.	Entered	r^2
					Empty Load								
Driving													
5	0.6226	1	0.4556	2									0.978
10	1.5758	1											0.888
15	0.9694	1							0.0761	2			0.941
20					0.8404	2			0.1804	1			0.935
Sinusoidal													
20	0.7133	1			0.6293	2							0.964
30	1.2216	1											0.950
					Half Load								
Driving													
5			0.4287	2			0.9192	1					0.983
10	0.4504	1	0.6309	3					0.1380	2			0.972
15	1.5982	1											0.895
20									0.2857	1	1.2517	2	0.938
Sinusoidal													
20					0.7872	2	1.1840	1	0.0666	3			0.993
30	1.7221	1											0.855
					Full Load								
Driving													
5	0.8640	1	0.3091	2									0.973
10	1.6439	1							0.1176	2			0.969
15	1.1616	1							0.1574	2			0.979
20	1.9135	2							0.2906	1			0.972
Sinusoidal													
20					1.5717	1			0.1930	2			0.972
30					1.2231	2			0.2406	1			0.954

Note: Variables entered to 0.05 significance level

TABLE B-7. COEFFICIENTS FOR STEPWISE MULTIPLE REGRESSION ANALYSIS
TEST CYCLE NO_x EMISSIONS AS A FUNCTION OF MODAL NO_x EMISSIONS FOR NINE GASOLINE TRUCKS

Chassis Cycle	16" Coeff.	16" Entered	Idle Coeff.	Idle Entered	10" Coeff.	10" Entered	19" Coeff.	19" Entered	3" Coeff.	3" Entered	CT Coeff.	CT Entered	r^2
Empty Load													
Driving													
5					0.0647	1							0.807
10					0.0508	2	0.3164	3	0.0755	1			0.994
15					0.1663	1			0.0850	2			0.986
20					0.2291	1			0.1468	2			0.964
Sinusoidal													
20					0.2848	1			0.1076	2			0.974
30					0.2874	1			0.1421	2			0.955
Half Load													
Driving													
5	0.1483	1							0.0309	2			0.960
10	0.2017	2							0.1051	1			0.988
15					0.1873	1			0.0725	2			0.981
20					0.2112	1			0.1542	2			0.981
Sinusoidal													
20	0.7461	2							0.2369	1			0.957
30	0.8886	2							0.2290	1			0.960
Full Load													
Driving													
5					0.0345	2			0.0416	1			0.952
10			12.4960	3	0.0772	2			0.0701	1			0.992
15			12.8974	3	0.2005	1			0.0540	2			0.993
20			19.4349	3	0.1893	1			0.1177	2			0.993
Sinusoidal													
20	0.6496	2							0.2718	1			0.962
30	0.8185	2							0.2197	1			0.988

Note: Variables entered to 0.05 significance level

TABLE B-8. COEFFICIENTS FOR STEPWISE MULTIPLE REGRESSION ANALYSIS
TEST CYCLE FUEL RATE AS A FUNCTION OF MODAL FUEL RATE FOR NINE GASOLINE TRUCKS

Chassis	16"		Idle		10"		19"		3"		CT		
Cycle	Coeff.	Entered	Coeff.	Entered	Coeff.	Entered	Coeff.	Entered	Coeff.	Entered	Coeff.	Entered	r^2
							Empty Load						
Driving													
5	0.4762	1											0.990
10	0.7319	1											0.994
15							1.4125	1			-0.6638	2	0.996
20							1.8532	1			-0.8175	2	0.997
Sinusoidal													
20							1.4936	1					0.986
30							1.5420						0.983
							Half Load						
Driving													
5	0.4875	1											0.990
10	0.7009	1											0.995
15							1.1945	1					0.994
20							2.1258	1			-1.0751	2	0.996
Sinusoidal													
20							1.6425	1					0.993
30							1.6810	1					0.991
							Full Load						
Driving													
5	0.5247	1											0.992
10	0.8794	1											0.993
15									0.3872	1			0.987
20									0.5414	1			0.988
Sinusoidal													
20			-1.4437	2			2.4097	1					0.996
30			-2.0160	2			2.6468	1					0.994

Note: Variables entered to 0.05 significance level

TABLE B-9. REGRESSION COEFFICIENTS FOR TEST CYCLE HC EMISSIONS AS A FUNCTION OF 9 MODE HC EMISSIONS FOR NINE GASOLINE TRUCKS

	16 in.	Idle	10 in.	19 in.	3 in.	CT
Full Load						
Driving						
10	0.0000	0.7464	0.0000	0.0000	0.0000	0.2536
15	0.0000	0.8357	0.0000	0.0000	0.0331	0.1312
20	0.0000	0.7591	0.0000	0.0000	0.0000	0.2409
Sinusoidal						
20	0.0000	0.4423	0.0000	0.0000	0.0000	0.5577
30	0.0000	0.6410	0.0000	0.0000	0.0000	0.3590
Half Load						
Driving						
10	0.0000	0.8435	0.0000	0.0000	0.0000	0.1565
15	0.1462	0.7296	0.0095	0.0000	0.0218	0.0929
20	0.0000	0.6443	0.0000	0.0879	0.1190	0.1489
Sinusoidal						
20	0.0000	0.3776	0.0000	0.0000	0.2083	0.4140
30	0.0000	0.5439	0.0000	0.0231	0.2107	0.2224
Empty Load						
Driving						
10	0.0000	0.8636	0.0000	0.0000	0.0000	0.1364
15	0.0000	0.7104	0.1940	0.0162	0.0062	0.0732
20	0.0000	0.7129	0.0000	0.1108	0.0658	0.1104
Sinusoidal						
20	0.0015	0.5002	0.0000	0.0000	0.2029	0.2954
30	0.1813	0.3965	0.1371	0.0000	0.2664	0.0187

TABLE B-10. REGRESSION COEFFICIENTS FOR TEST CYCLE CO EMISSIONS AS A FUNCTION OF 9 MODE CO EMISSIONS FOR NINE GASOLINE TRUCKS

	16 in.	Idle	10 in.	19 in.	3 in.	CT
Full Load						
Driving						
10	0.1570	0.3082	0.3326	0.0000	0.2022	0.0000
15	0.6791	0.0261	0.1022	0.0000	0.1927	0.0000
20	0.2014	0.0000	0.3750	0.0000	0.4236	0.0000
Sinusoidal						
20	0.0000	0.0000	0.7311	0.0000	0.2689	0.0000
30	0.0000	0.0865	0.6278	0.0000	0.2857	0.0000
Half Load						
Driving						
10	0.0000	0.6180	0.2195	0.0000	0.1625	0.0000
15	0.0955	0.5993	0.2015	0.0000	0.1038	0.0000
20	0.0000	0.4045	0.2984	0.0000	0.2971	0.0000
Sinusoidal						
20	0.0297	0.2184	0.5934	0.0000	0.1585	0.0000
30	0.0000	0.3792	0.4867	0.0000	0.1341	0.0000
Empty Load						
Driving						
10	0.0159	0.5501	0.3272	0.0000	0.1068	0.0000
15	0.3142	0.3982	0.2057	0.0000	0.0820	0.0000
20	0.0000	0.3684	0.4528	0.0000	0.1787	0.0000
Sinusoidal						
20	0.0232	0.3251	0.6054	0.0000	0.0463	0.0000
30	0.4052	0.2928	0.2577	0.0000	0.0444	0.0000

TABLE B-11. REGRESSION COEFFICIENTS FOR TEST CYCLE NO_x EMISSIONS AS A FUNCTION OF 9 MODE NO_x EMISSIONS FOR NINE GASOLINE TRUCKS

	16 in.	Idle	10 in.	19 in.	3 in.	CT
Full Load						
Driving						
10	0.0000	0.6697	0.0864	0.1658	0.0781	0.0000
15	0.0000	0.5591	0.2102	0.1682	0.0624	0.0000
20	0.0000	0.2968	0.2015	0.3732	0.1286	0.0000
Sinusoidal						
20	0.3777	0.0000	0.0902	0.0000	0.2555	0.2766
30	0.7740	0.0000	0.0000	0.0000	0.2260	0.0000
Half Load						
Driving						
10	0.0554	0.6065	0.0386	0.2049	0.0947	0.0000
15	0.0000	0.3146	0.1756	0.4465	0.0633	0.0000
20	0.0000	0.1631	0.1983	0.4943	0.1442	0.0000
Sinusoidal						
20	0.4157	0.0000	0.0959	0.2718	0.2167	0.0000
30	0.4738	0.0000	0.1151	0.1997	0.2115	0.0000
Empty Load						
Driving						
10	0.0000	0.5670	0.0504	0.3074	0.0752	0.0000
15	0.0000	0.4197	0.1570	0.3456	0.0776	0.0000
20	0.0000	0.0000	0.2117	0.6546	0.1337	0.0000
Sinusoidal						
20	0.0000	0.0000	0.2684	0.6366	0.0949	0.0000
30	0.1043	0.0000	0.2460	0.5167	0.1330	0.0000

TABLE B-12. REGRESSION COEFFICIENTS FOR TEST CYCLE FUEL RATE AS A FUNCTION OF 9 MODE FUEL RATE FOR NINE GASOLINE TRUCKS

	16 in.	Idle	10 in.	19 in.	3 in.	CT
Full Load						
Driving						
10	0.8298	0.1698	0.0000	0.0000	0.0004	0.0000
15	0.0000	0.1780	0.0000	0.6375	0.1845	0.0000
20	0.4706	0.0000	0.0000	0.2421	0.2873	0.0000
Sinusoidal						
20	0.0000	0.0000	0.6356	0.3076	0.0568	0.0000
30	0.0000	0.0000	0.5634	0.3423	0.0943	0.0000
Half Load						
Driving						
10	0.3436	0.0749	0.0000	0.5816	0.0000	0.0000
15	0.5182	0.0000	0.0000	0.4811	0.0007	0.0000
20	0.0000	0.0000	0.1031	0.6702	0.2267	0.0000
Sinusoidal						
20	0.0000	0.0000	0.5866	0.4134	0.0000	0.0000
30	0.0000	0.0000	0.6228	0.3772	0.0000	0.0000
Empty Load						
Driving						
10	0.0371	0.0165	0.0000	0.9464	0.0000	0.0000
15	0.1777	0.0000	0.0000	0.7964	0.0262	0.0000
20	0.5677	0.0000	0.0000	0.3121	0.1202	0.0000
Sinusoidal						
20	0.0000	0.0000	0.4500	0.5500	0.0000	0.0000
30	0.0000	0.0000	0.4956	0.5044	0.0000	0.0000

TABLE B-13. REGRESSION COEFFICIENTS FROM NON-LINEAR REGRESSION ANALYSIS, TEST CYCLE COMBINED EMISSIONS AND FUEL RATE AS A FUNCTION OF 9-MODE COMBINED EMISSIONS AND FUEL RATE, FOR NINE GASOLINE TRUCKS

Cycle	16"	Idle	10"	19"	3"	CT	r^2
			Full Load				
Driving							
5	0.2728	0.5884	0.0000	0.0000	0.0339	0.0000	0.987
10	0.2512	0.8535	0.0000	0.0000	0.1545	0.0065	0.978
15	0.3951	0.3172	0.0000	0.0000	0.1980	0.0000	0.982
20	0.2546	0.7200	0.0000	0.0000	0.3660	0.0000	0.976
Sinusoidal							
20	0.0000	0.0000	0.1409	0.6236	0.2214	0.4109	0.973
30	0.3344	0.2344	0.0788	0.2857	0.2438	0.0450	0.974
40	0.0000	0.2059	0.7675	0.0000	0.1616	0.0000	0.986
			Half Load				
Driving							
5	0.0000	0.6068	0.0000	0.3562	0.0224	0.0000	0.983
10	0.2014	0.7154	0.0124	0.0000	0.1447	0.0016	0.987
15	0.4574	0.5404	0.0000	0.0785	0.0809	0.0000	0.986
20	0.0000	0.5841	0.2251	0.0000	0.2820	0.0000	0.985
Sinusoidal							
20	0.0000	0.1229	0.0520	1.0069	0.0946	0.3820	0.985
30	0.0000	0.2505	0.2913	0.5793	0.0887	0.2203	0.985
40	0.0642	0.1535	0.7678	0.0000	0.0922	0.0000	0.992
			Empty Load				
Driving							
5	0.0710	0.6258	0.0000	0.2708	0.0119	0.0000	0.984
10	0.3210	0.6093	0.0000	0.0000	0.0912	0.0288	0.984
15	0.4854	0.3165	0.0203	0.0000	0.0871	0.0000	0.986
20	0.1469	0.3954	0.2616	0.0000	0.1755	0.0000	0.989
Sinusoidal							
20	0.0000	0.1623	0.3045	0.6762	0.0081	0.2222	0.981
30	0.3293	0.1118	0.1961	0.5905	0.0142	0.0000	0.980
40	0.3162	0.0546	0.5882	0.0000	0.0664	0.0000	0.993

Note: Coefficients constrained to be positive

TABLE B-14. REGRESSION COEFFICIENTS FOR COMBINED EMISSIONS AND FUEL RATE FOR TEST CYCLES AS A FUNCTION OF 9-MODE COMBINED EMISSIONS AND FUEL RATE COEFFICIENTS NORMALIZED TO SUM TO 1.0

Cycle	16"	Idle	10"	19"	3"	CT
			Full Load			
Driving						
5	0.3048	0.6573	0.0000	0.0000	0.0379	0.0000
10	0.1985	0.6743	0.0000	0.0000	0.1221	0.0051
15	0.4341	0.3485	0.0000	0.0000	0.2175	0.0000
20	0.1899	0.5371	0.0000	0.0000	0.2731	0.0000
Sinusoidal						
20	0.0000	0.0000	0.1009	0.4464	0.1585	0.2942
30	0.2736	0.1918	0.0645	0.2338	0.1995	0.0368
40	0.0000	0.1814	0.6762	0.0000	0.1424	0.0000
			Half Load			
Driving						
5	0.0000	0.6158	0.0000	0.3615	0.0227	0.0000
10	0.1872	0.6652	0.0115	0.0000	0.1346	0.0015
15	0.3953	0.4670	0.0000	0.0678	0.0699	0.0000
20	0.0000	0.5353	0.2063	0.0000	0.2584	0.0000
Sinusoidal						
20	0.0000	0.0741	0.0314	0.6072	0.0570	0.2303
30	0.0000	0.1752	0.2037	0.4050	0.0620	0.1541
40	0.0596	0.1424	0.7125	0.0000	0.0855	0.0000
			Empty Load			
Driving						
5	0.0724	0.6389	0.0000	0.2765	0.0121	0.0000
10	0.3056	0.5801	0.0000	0.0000	0.0868	0.0274
15	0.5339	0.3481	0.0223	0.0000	0.0957	0.0000
20	0.1500	0.4038	0.2671	0.0000	0.1792	0.0000
Sinusoidal						
20	0.0000	0.1182	0.2217	0.4924	0.0059	0.1618
30	0.2652	0.0900	0.1579	0.4754	0.0114	0.0000
40	0.3084	0.0532	0.5736	0.0000	0.0647	0.0000

TABLE B-15. REGRESSION COEFFICIENTS FOR TEST CYCLE HC EMISSIONS AS A FUNCTION OF 9-MODE HC EMISSIONS WITH WOT REPLACING 3" MODE FOR NINE GASOLINE TRUCKS

	16 in.	Idle	10 in.	19 in.	WOT	CT	r^2	$\sqrt{MSE}$
Full Load								
Driving								
10	0.0000	0.7464	0.0000	0.0000	0.0000	0.2536	0.950	2.883
15	0.0000	0.8083	0.0000	0.0000	0.0736	0.1181	0.989	1.019
20	0.0000	0.6948	0.0000	0.0000	0.0838	0.2214	0.972	2.033
Sinusoidal								
20	0.0000	0.4423	0.0000	0.0000	0.0000	0.5577	0.944	4.548
30	0.0000	0.6389	0.0000	0.0000	0.0028	0.3583	0.976	2.180
Half Load								
Driving								
10	0.0000	0.8386	0.0000	0.0000	0.0063	0.1550	0.968	1.825
15	0.0355	0.7278	0.0000	0.0921	0.0620	0.0827	0.984	1.022
20	0.0000	0.6255	0.0000	0.1170	0.1170	0.1406	0.974	1.574
Sinusoidal								
20	0.0000	0.4501	0.0000	0.0000	0.1442	0.4057	0.970	2.740
30	0.0245	0.5873	0.0000	0.0682	0.0816	0.2384	0.977	1.756
Empty Load								
Driving								
10	0.0000	0.8636	0.0000	0.0000	0.0000	0.1364	0.985	1.194
15	01649	0.6888	0.0035	0.0000	0.0839	0.0589	0.989	0.791
20	0.0000	0.6854	0.0000	0.1243	0.0910	0.0993	0.984	1.078
Sinusoidal								
20	0.0504	0.5076	0.0000	0.0000	0.1521	0.2899	0.973	2.178
30	0.3391	0.4187	0.0000	0.0323	0.1887	0.0212	0.975	1.062

TABLE B-16. REGRESSION COEFFICIENTS FOR TEST CYCLE CO EMISSIONS AS A FUNCTION OF 9-MODE CO EMISSIONS WITH WOT REPLACING 3" MODE FOR NINE GASOLINE TRUCKS

	16 in.	Idle	10 in.	19 in.	WOT	CT	r^2	$\sqrt{MSE}$
Full Load								
Driving								
10	0.0000	0.1207	0.0000	0.7282	0.1511	0.0000	0.982	14.494
15	0.0000	0.0000	0.0000	0.8698	0.1302	0.0000	0.952	21.532
20	0.0000	0.0000	0.0000	0.7215	0.2785	0.0000	0.950	38.390
Sinusoidal								
20	0.0000	0.0000	0.3229	0.4996	0.1775	0.0000	0.918	37.069
30	0.0000	0.0000	0.0000	0.8074	0.1926	0.0000	0.946	30.022
Half Load								
Driving								
10	0.0000	0.3799	0.0000	0.5149	0.1052	0.0000	0.952	19.998
15	0.0000	0.4638	0.0000	0.4592	0.0769	0.0000	0.980	10.833
20	0.0000	0.2284	0.0000	0.4594	0.1825	0.0937	0.883	44.370
Sinusoidal								
20	0.0000	0.0000	0.0281	0.8504	0.1214	0.0000	0.971	16.198
30	0.0000	0.0000	0.0085	0.3750	0.1036	0.5129	0.954	18.267
Empty Load								
Driving								
10	0.0000	0.3952	0.0000	0.5266	0.0782	0.0000	0.978	11.427
15	0.0000	0.1788	0.0000	0.5941	0.0635	0.1636	0.958	13.653
20	0.0000	0.0000	0.0000	0.5914	0.1231	0.2855	0.923	26.132
Sinusoidal								
20	0.0000	0.2961	0.4914	0.1739	0.0386	0.0000	0.986	7.316
30	0.1412	0.0000	0.0254	0.3708	0.0474	0.4151	0.995	3.856

TABLE B-17. REGRESSION COEFFICIENTS FOR TEST CYCLE NO_x EMISSIONS AS A FUNCTION OF 9-MODE NO_x EMISSIONS WITH WOT REPLACING 3" MODE FOR NINE GASOLINE TRUCKS

	16 in.	Idle	10 in.	19 in.	WOT	CT	r^2	$\sqrt{MSE}$
Full Load								
Driving								
10	0.0000	0.5363	0.1243	0.2506	0.0888	0.0000	0.909	0.854
15	0.0000	0.4427	0.2417	0.2494	0.0662	0.0000	0.968	0.795
20	0.0000	0.0297	0.2697	0.5779	0.1228	0.0000	0.933	1.441
Sinusoidal								
20	0.0000	0.0000	0.3697	0.5383	0.0920	0.0000	0.836	2.994
30	0.0000	0.0000	0.2946	0.4516	0.2538	0.0000	0.889	2.336
Half Load								
Driving								
10	0.0000	0.4000	0.1019	0.4119	0.0863	0.0000	0.874	0.940
15	0.0000	0.2301	0.2033	0.4828	0.0837	0.0000	0.968	0.737
20	0.0000	0.0000	0.2873	0.5950	0.1177	0.0000	0.923	1.638
Sinusoidal								
20	0.0000	0.0000	0.3246	0.4819	0.1935	0.0000	0.871	2.569
30	0.0000	0.0000	0.3392	0.4304	0.2303	0.0000	0.893	2.465
Empty Load								
Driving								
10	0.0000	0.3553	0.0972	0.5032	0.0444	0.0000	0.885	0.791
15	0.0000	0.2639	0.1975	0.4613	0.0772	0.0000	0.955	0.847
20	0.0000	0.0000	0.3121	0.6137	0.0741	0.0000	0.922	1.704
Sinusoidal								
20	0.0000	0.0000	0.3172	0.5628	0.1200	0.0000	0.959	1.262
30	0.0000	0.0000	0.3320	0.4849	0.1832	0.0000	0.935	1.772

TABLE B-18. REGRESSION COEFFICIENTS FOR TEST CYCLE FUEL RATE AS A FUNCTION OF 9-MODE FUEL RATE WITH WOT REPLACING 3" MODE FOR NINE GASOLINE TRUCKS

	16 in.	Idle	10 in.	19 in.	WOT	CT	r^2	$\sqrt{MSE}$
Full Load								
Driving								
10	0.8311	0.1689	0.0000	0.0000	0.0000	0.0000	0.993	18.974
15	0.1967	0.0000	0.0000	0.7106	0.0927	0.0000	0.984	33.031
20	0.8008	0.0000	0.0000	0.0000	0.1992	0.0000	0.985	43.388
Sinusoidal								
20	0.0000	0.0000	0.7633	0.2367	0.0000	0.0000	0.988	38.128
30	0.0000	0.0000	0.7754	0.2246	0.0000	0.0000	0.984	44.248
Half Load								
Driving								
10	0.3436	0.0749	0.0000	0.5816	0.0000	0.0000	0.994	15.686
15	0.5230	0.0000	0.0000	0.4770	0.0000	0.0000	0.994	17.657
20	0.0000	0.0000	0.6125	0.3875	0.0000	0.0000	0.992	28.711
Sinusoidal								
20	0.0000	0.0000	0.5866	0.4134	0.0000	0.0000	0.991	30.211
30	0.0000	0.0000	0.6228	0.3772	0.0000	0.0000	0.989	33.008
Empty Load								
Driving								
10	0.0371	0.0165	0.0000	0.9464	0.0000	0.0000	0.994	15.245
15	0.3201	0.0000	0.0100	0.6699	0.0000	0.0000	0.993	18.118
20	0.5345	0.0000	0.2815	0.1841	0.0000	0.0000	0.994	22.639
Sinusoidal								
20	0.0000	0.0000	0.4500	0.5500	0.0000	0.0000	0.985	35.657
30	0.0000	0.0000	0.4956	0.5044	0.0000	0.0000	0.981	40.470

TABLE B-19. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 1 10MPH
TEST #2

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	.18	.37	.75	1.12	.18	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	.18	.37	0	0	.75	.56	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	.18	0	.18	0	.18	0	0	0	0	0	0	0	0	0
5	.18	0	0	0	.37	0	0	.18	.56	.18	0	0	.18	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	.18	.37	0	.37	.18	0	.18	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	.18	.37	.18	0	.18	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	.18	0	0	.56	.18	0	.18	.37	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	.18	0	.18	.18	.18	.56	.37	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	.18	.18	.37	0	0	.37	.37	.18	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	.18	.56	.37	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	.37	.18	.37	.37	0	.37	0	0	0	0	0	0	0	0	0	0
13	0	0	0	.37	0	0	0	.56	0	.37	.93	0	.18	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	.18	.75	0	.18	.56	.56	.18	0	0	0	0	0	0	0	0	0
15	0	0	0	0	.18	.18	0	.75	.75	.93	.18	.18	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	.18	.37	.75	.18	.75	.75	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	.93	.18	0	.56	.37	.75	.37	.18	.18	0	0	0	0	0	0	0	0	0
18	0	0	.18	.18	.37	0	0	.56	0	2.81	0	0	.56	0	0	0	0	0	0	0	0	0
19	0	0	0	0	.37	0	0	.18	0	.93	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	.37	0	0	0	.18	0	0	1.87	0	.37	0	0	0	0	0	0	0	0	0	0
21	0	0	15.07	23.78	0	0	.18	.18	.18	.75	0	.18	0	0	0	0	0	0	0	0	0	0
22	0	0	0	1.12	.56	.37	0	.37	.56	.37	.18	.18	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	2.44	2.06	1.69	2.25	1.12	.56	.37	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-20. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 2 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	.17	0	0	0	0	.17	.35	1.06	.70	.35	.53	0	.17	0	0	0	0	0	0	0
2	0	0	0	0	.17	0	0	0	.17	.35	0	0	0	.17	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	.17	0	0	.35	.17	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	.17	0	0	.35	0	0	0	0	0	0	0	0	0
5	0	0	0	0	.17	0	0	0	0	.35	0	.17	.17	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	.17	.35	.17	.17	0	.17	.17	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	.35	.17	0	.53	0	0	.17	.70	0	.17	0	0	0	0	0	0	0
8	0	0	0	0	0	0	.17	0	.17	0	0	.35	0	0	.17	0	0	0	0	0	0	0
9	0	0	0	0	0	0	.17	0	0	.17	0	.35	.35	0	0	0	0	0	0	0	0	0
10	0	0	0	.17	0	0	.17	.35	.17	.17	0	.53	.35	0	.17	0	0	0	0	0	0	0
11	0	0	.17	.17	0	.35	.17	.17	.17	.17	.70	0	.53	.35	.17	0	0	0	0	0	0	0
12	0	0	0	0	0	0	.17	.35	.17	0	.35	.70	.53	.17	0	.17	0	0	0	0	0	0
13	0	0	0	0	0	.17	0	0	0	0	0	.17	.53	0	0	.17	0	0	0	0	0	0
14	0	0	0	0	.17	0	0	.17	.17	.35	.35	0	.53	.17	0	0	0	0	0	0	0	0
15	0	0	0	0	.35	.17	0	.17	.35	0	1.06	0	0	.17	0	.70	0	0	0	0	0	0
16	0	0	0	.17	.35	.35	0	0	.35	0	1.23	0	.70	.17	0	.17	0	0	0	0	0	0
17	0	0	0	3.35	.35	0	0	0	.53	.35	.70	0	1.06	.35	0	.17	0	0	0	0	0	0
18	0	0	0	24.82	10.72	0	0	.17	1.06	.53	0	0	.70	.53	0	0	0	0	0	0	0	0
19	0	0	0	0	1.59	.70	0	.35	.88	.35	.17	.17	.70	.35	0	0	0	0	0	0	0	0
20	0	0	0	0	.88	0	.17	.17	.17	.17	.35	0	.35	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	1.06	.35	.88	.17	.17	.35	0	0	0	.17	0	0	0	0	0	0	0
22	0	0	0	0	0	0	.53	1.41	.53	.53	0	.35	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	.70	.88	1.06	.70	.35	.17	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 9-21. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 3 10MPH TEST 62	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	.17	0	0	.35	.70	.88	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	.17	0	0	.35	.35	.88	.70	.35	.17	0	0	0	0	0	0	0
	3	0	0	0	.17	0	0	0	.17	0	.35	.35	0	.17	.17	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	.17	0	0	.17	.17	0	0	.35	0	0	0	0	0	0	0
	5	0	0	0	0	.35	0	0	0	0	0	0	0	0	.17	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	.17	.17	0	.17	0	0	0	0	.88	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	.17	0	0	0	.17	.17	0	0	0	.35	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	.17	0	0	.17	.17	.17	.17	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	.17	0	0	0	.35	.17	.17	.17	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	.17	.17	.17	0	.17	.17	.17	0	0	0	0	0	0
	11	0	0	0	0	.17	0	0	0	0	.17	0	.17	.35	.17	.17	.17	0	0	0	0	0	0
	12	0	0	0	0	.17	0	0	0	.35	.35	.52	.17	0	.17	0	.17	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	0	.35	.17	.35	0	.52	.35	.17	0	0	0	0	0	0
	14	0	0	0	0	0	.35	0	.17	.35	0	0	.35	0	.17	1.05	.35	0	0	0	0	0	0
	15	0	0	0	0	0	.17	.17	.17	.17	.17	0	.17	.35	0	.17	0	0	0	0	0	0	0
	16	0	0	0	0	0	.17	0	.17	.88	.17	.35	1.93	0	.17	.17	0	0	0	0	0	0	0
	17	0	0	0	0	.17	0	.17	0	.17	.52	0	0	0	.35	.35	0	0	0	0	0	0	0
	18	0	0	.17	.35	0	.52	.17	.35	.35	0	.52	.52	0	0	.35	0	0	0	0	0	0	0
	19	0	0	0	1232	.35	.35	.17	.17	.17	.17	.35	.70	.17	0	.52	0	0	0	0	0	0	0
	20	0	0	0	3292	.17	0	.17	0	.17	.35	1.05	.17	0	0	.35	0	0	0	0	0	0	0
	21	0	0	0	.88	.88	.35	.17	0	0	.35	.35	0	0	0	.17	0	0	0	0	0	0	0
	22	0	0	0	0	.52	.17	0	0	0	0	.35	0	.17	0	0	0	0	0	0	0	0	0
	23	0	0	0	0	.17	1.23	.35	.52	1.23	.17	.17	.17	0	0	.17	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	1.23	1.93	1.40	.70	.17	.35	.35	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	.88	.70	.52	.17	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-23. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 4 10MPH
TEST 67

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	.52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	.17	.69	1.39	.87	.34	.17	0	0	0	0	0	0	0	0	0	0	0
2	0	0	.17	0	0	0	0	.52	.52	.17	.17	0	0	0	0	0	0	0	0	0	0	0
3	0	0	.17	0	.17	.34	0	0	.17	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	.17	0	0	0	.34	.34	.17	.17	.17	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	.17	0	.17	0	0	.17	0	.34	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	.17	0	0	.34	.34	.34	.17	0	0	0	0	0	0	0	0	0	0	0
7	0	0	.17	0	0	.17	0	0	.34	.17	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	.52	.17	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	.17	0	.17	0	0	.17	.34	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	.17	.34	.17	0	.17	.34	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	.17	0	.34	.17	0	.34	0	.52	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	.17	0	.52	0	.69	0	.52	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	.17	.52	.34	.52	.69	.69	0	.34	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	.69	.87	.52	.17	.34	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	.17	0	.17	.17	.52	0	.34	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	.34	0	0	.52	.17	.69	0	.34	0	0	0	0	0	0	0	0	0	0	0
17	0	0	4.54	0	.69	0	.34	.52	1.22	.17	.34	0	0	0	0	0	0	0	0	0	0	0
18	0	0	25.69	.34	1.74	.17	.69	.17	.87	0	.17	0	0	0	0	0	0	0	0	0	0	0
19	0	0	1.82	7.51	1.22	.17	.34	.52	.17	.17	.17	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	1.22	.17	3.32	1.57	1.22	.69	.17	.52	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	1.22	2.79	3.37	1.57	.69	.52	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	.52	.17	1.04	1.22	1.04	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-23. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 5 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	.18	1.10	2.02	2.57	1.65	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	.36	.91	1.65	1.65	.18	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	.18	0	.18	0	0	.18	0	0	0	0	0	0	0	0
4	0	0	0	0	.18	0	0	.18	0	.36	.18	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	.18	.18	0	0	.18	.36	0	.36	.18	0	0	.18	.18	.18	0	0	0	0
6	0	0	0	.18	0	0	.36	.18	0	.18	.18	0	0	.18	0	0	.18	0	0	0	0	0
7	0	0	0	.18	0	0	0	0	.18	.18	0	0	.18	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	.36	0	0	.36	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	.55	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	.36	.18	0	.36	0	0	0	0	.18	0	0	0	0	0
11	0	0	0	0	0	0	0	0	.55	0	0	.36	0	.18	0	0	.18	0	0	0	0	0
12	0	0	0	.18	.18	.18	0	0	.18	0	.18	0	.18	0	0	0	0	0	0	0	0	0
13	0	0	.91	.18	0	0	0	0	.73	.18	0	.36	0	.18	0	0	0	.18	0	0	0	0
14	0	0	1.28	0	0	0	0	0	.18	0	0	.18	0	0	0	0	.18	0	0	0	0	0
15	0	0	6.63	0	0	0	0	.36	0	0	0	.18	.36	0	0	0	.18	0	0	0	0	0
16	0	0	34.19	0	.18	0	.36	0	.55	0	.18	.73	0	0	0	0	0	0	0	0	0	0
17	0	0	3.86	.18	0	.73	.18	0	0	0	.18	.73	0	.36	0	0	0	0	0	0	0	0
18	0	0	0	0	0	.18	.18	.36	0	0	.36	.73	.18	.18	0	0	.18	.18	0	0	0	0
19	0	0	.18	0	0	.18	.18	0	0	0	.36	.55	0	.18	0	0	.18	0	0	0	0	0
20	0	0	0	.55	.55	.18	0	.18	0	.36	.36	.91	0	0	0	0	.18	0	0	0	0	0
21	0	0	0	0	.36	.18	.18	0	.18	0	.36	.55	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	.36	1.47	.55	.36	0	.55	.36	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	.73	2.20	1.65	1.47	.73	.36	0	0	0	.18	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	1.10	.18	.36	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	.18	.18	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-24. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 6 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	.17	0	.17	.17	0	.70	.53	.53	.53	0	.17	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	.17	.17	.70	0	0	.35	.35	0	0	0	0	0	0	0
4	0	0	0	0	0	.17	0	0	0	0	0	.35	0	.35	0	0	0	0	0	0	0	0
5	0	0	0	0	0	.35	0	0	0	0	.53	0	0	.17	0	0	0	0	0	0	0	0
6	0	0	0	0	0	.17	0	0	.17	.35	0	0	.35	.17	0	0	0	0	0	0	0	0
7	0	0	0	.17	0	0	.17	.17	0	.53	0	0	.17	.17	0	0	0	0	0	0	0	0
8	0	0	0	0	.17	0	0	0	0	.17	.17	0	.17	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	.17	.17	.17	0	.35	.17	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	.17	.17	0	0	.17	0	0	.17	0	.35	0	0	0	0	0	0	0
11	0	0	0	.17	0	.17	0	0	0	.17	.17	0	0	.17	.35	0	0	0	0	0	0	0
12	0	0	.17	0	0	0	0	0	.17	0	.17	.35	0	.35	0	0	0	0	0	0	0	0
13	0	0	.35	0	0	.17	.17	.17	.17	.53	.17	.17	0	.53	.70	.53	0	0	0	0	0	0
14	0	0	3.36	.17	0	0	.17	0	.35	.17	0	.35	.53	.53	.53	.17	0	0	0	0	0	0
15	0	0	3.36	4.60	.17	0	.17	0	.17	.53	0	.70	.17	.17	.17	.17	0	0	0	0	0	0
16	0	0	0	4.63	0	0	0	.17	.35	.88	.17	.88	0	.53	.35	0	0	0	0	0	0	0
17	0	0	0	8.15	.35	.17	0	0	.53	0	.35	1.95	0	.17	.53	.17	0	0	0	0	0	0
18	0	0	0	10.08	.88	.53	.35	.35	.70	0	.35	.70	0	.17	.17	.35	0	0	0	0	0	0
19	0	0	0	.17	1.59	.35	0	0	.35	.17	.88	.88	.17	0	0	0	0	0	0	0	0	0
20	0	0	0	0	.35	1.41	0	0	0	.17	.70	.53	0	0	.35	.17	0	0	0	0	0	0
21	0	0	0	0	0	.70	.53	0	.17	.17	.35	.17	.17	0	.17	0	0	0	0	0	0	0
22	0	0	0	0	0	0	.70	1.41	1.24	.35	1.56	0	.17	.17	.17	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	.17	.88	1.06	1.24	.17	.35	.53	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	.17	.70	.35	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-25. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 7 10MPH
TEST 62

VAC \ RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	.35	.35	1.23	.70	.70	.17	.17	.17	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	.17	.17	.35	.35	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	.17	.17	.35	0	0	0	.17	0	0	0	0	0
5	0	0	0	0	0	.17	0	0	.17	0	0	.17	.17	.17	0	.17	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	.17	0	0	0	0	.17	0	.17	.17	0	0	0	0
7	0	0	0	0	.17	.70	0	.17	.17	0	0	.17	0	0	0	.17	0	0	0	0	0	0
8	0	0	0	0	0	.17	.17	0	0	0	.17	0	.17	.17	.70	.17	.17	.17	0	0	0	0
9	0	0	0	0	.17	.17	.17	0	0	0	.17	.17	.17	.17	.17	0	.35	0	0	0	0	0
10	0	0	0	0	0	.17	0	.17	.17	.17	0	0	0	.17	.35	0	.17	0	0	0	0	0
11	0	0	0	0	0	0	0	.17	.17	0	.35	0	0	0	.17	0	.17	.35	0	0	0	0
12	0	0	0	0	.17	0	.17	.17	.17	0	.52	.17	.17	.35	.52	0	0	0	0	0	0	0
13	0	0	0	0	0	.17	0	0	0	.17	.35	0	.70	.70	.17	.17	1.23	.35	0	0	0	0
14	0	0	0	0	.17	0	.17	0	0	0	.52	0	.17	0	.17	0	.17	0	0	0	0	0
15	0	0	0	0	0	0	0	0	.17	0	.52	0	.17	.35	.17	0	.17	.35	0	0	0	0
16	0	0	0	.17	0	.17	0	0	0	0	1.05	.52	.35	.70	1.23	0	0	.17	0	0	0	0
17	0	0	0	.35	.17	.35	.17	0	0	0	1.05	.35	0	1.40	.88	0	.17	.35	0	0	0	0
18	0	0	0	44.19	0	.35	0	.17	0	0	.70	.52	0	.17	0	0	0	.35	0	0	0	0
19	0	0	0	.52	.35	.17	0	0	0	0	.52	.88	0	.52	.17	0	.17	0	0	0	0	0
20	0	0	0	0	.52	.35	0	0	0	0	.52	.17	.17	.52	0	0	.17	0	0	0	0	0
21	0	0	0	0	.52	.17	0	0	0	.35	.17	0	0	0	0	.35	0	0	0	0	0	0
22	0	0	0	0	0	.17	.70	.17	.52	.70	0	0	.35	.17	.17	.17	0	0	0	0	0	0
23	0	0	0	0	0	0	.52	1.05	1.23	.88	1.05	.52	.70	0	.52	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	.17	0	.35	.52	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-26. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 8 10MPH
TEST 62

VAC \ RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	.17	0	.17	0	.17	.35	.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	.17	.70	2.67	1.61	.35	.35	0	0	0	0	0	0	0	0	0	0
2	.17	0	0	0	0	0	.17	.17	.17	.35	.17	.35	.17	0	0	0	0	0	0	0	0	0
3	0	0	.35	.35	0	0	0	0	0	.17	0	.17	0	0	0	0	0	0	0	0	0	0
4	0	0	0	.17	0	0	0	0	.35	.35	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	.17	.35	.35	.17	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	.17	0	0	.17	.17	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	.35	.17	0	.17	0	0	0	0	0	.17	0	0	0	0	0	0	0
8	0	0	0	0	.17	.17	0	.17	0	.17	0	.35	.17	0	.17	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	.35	.35	0	.35	.17	.17	0	0	0	0	0	0	0	0	0
10	0	0	0	0	.17	0	0	0	0	0	.35	.35	.17	.17	0	0	0	0	0	0	0	0
11	0	0	0	0	.17	0	0	.35	0	.35	.17	.88	.17	0	0	0	0	0	0	0	0	0
12	0	0	0	.17	0	0	.17	.35	0	0	.17	0	.17	0	.17	0	0	0	0	0	0	0
13	0	.17	.17	0	0	.35	.17	.35	.35	.17	.53	0	0	.17	0	0	0	0	0	0	0	0
14	0	0	10.99	.17	0	.17	0	0	.70	.17	0	.17	.17	0	.17	0	0	0	0	0	0	0
15	0	0	12.21	0	0	0	0	.35	0	0	.35	0	.17	0	0	.17	0	0	0	0	0	0
16	0	0	.70	0	0	.17	0	.35	.17	.35	.17	.35	.17	0	0	0	0	0	0	0	0	0
17	0	0	0	.88	0	0	.17	.17	0	1.06	.70	0	.53	0	.35	0	0	0	0	0	0	0
18	0	0	0	.88	.17	.17	0	.53	.17	.53	0	.17	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	.35	.17	0	.35	.35	1.06	.88	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	1.06	.35	0	.35	0	.88	.17	.35	.17	0	.17	0	0	0	0	0	0	0
21	0	0	0	0	1.06	.17	0	.17	0	1.06	.53	.17	0	0	.17	0	0	0	0	0	0	0
22	0	0	0	0	.17	1.61	.35	.35	.17	.35	.17	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	.35	1.23	2.65	.88	.53	0	.17	.17	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	.70	.70	.53	.53	.35	0	.17	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-27. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 9 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	.16	0	.33	0	.33	.16	.66	3.16	2.33	.66	0	0	0	0	0	0	0	0
1	0	0	.16	0	.16	.16	.33	.16	.16	0	.33	.16	0	.16	.50	.33	.16	.16	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	.16	.33	0	0	0	0	0	0	0	0
3	0	0	0	0	.16	0	0	.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	.16	.16	0	0	0	0	0	0	.16	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	.16	0	.33	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	.16	0	.16	0	0	.16	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	.16	0	0	0	.16	.16	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	.16	.16	0	.16	0	0	0	0	.33	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	.16	0	0	.16	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	.16	0	0	.16	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	.16	.16	.16	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	.33	0	0	.50	0	.16	0	0	0	0	0	0	0
13	0	0	0	0	0	.16	.16	0	0	0	0	.16	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	.16	.16	0	0	.16	.16	.16	1.00	0	0	.33	0	.16	0	0	0	0	0
15	0	0	0	0	.16	0	0	0	.16	0	.33	0	0	0	.33	0	0	0	0	0	0	0
16	0	0	0	0	0	.33	0	0	.16	0	0	.16	0	0	.66	0	0	0	0	0	0	0
17	0	0	0	0	.83	.50	0	0	.16	.16	.66	0	0	0	1.66	0	0	0	0	0	0	0
18	0	0	0	0	.50	.66	0	0	1.00	0	.33	.33	0	0	.66	0	0	0	0	0	0	0
19	0	0	0	17.66	8.00	.50	.16	0	1.00	.16	0	.83	.16	.16	.83	0	0	0	0	0	0	0
20	0	0	0	1.83	27.00	.33	0	0	1.33	.16	0	.66	0	.16	.66	0	0	0	0	0	0	0
21	0	0	0	0	1.00	1.50	.33	0	.50	1.00	.33	0	0	.33	.16	0	0	0	0	0	0	0
22	0	0	0	0	0	.16	.16	0	0	0	.16	.33	0	.16	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	.33	.66	.83	.66	.16	.50	.16	.66	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	.50	.33	.33	.50	1.16	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-20. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 18 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	.15	0	0	0	0	0	0	0	0	.78	.78	.31	0	0	.15	0	0	0	.15	0	0	0
1	2.19	.47	.15	0	0	0	0	0	.15	.15	.31	3.26	2.35	.31	.15	0	0	0	.15	0	0	0
2	.15	0	0	0	0	0	0	0	.15	0	.15	.15	0	.15	0	0	.15	.15	0	0	0	0
3	0	0	.15	0	.15	0	0	0	0	0	0	.15	0	.15	0	0	0	.15	0	0	0	0
4	0	0	.15	.15	0	0	0	0	.15	.15	.15	.31	.15	0	.15	0	.15	0	.15	0	0	0
5	0	0	0	0	0	0	0	0	.15	0	.15	.15	0	.15	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	.15	.15	0	0	0	0	0	0	0	0	0	0
7	0	.15	0	0	.15	0	0	0	.15	0	.15	0	0	0	.15	0	0	0	0	0	0	0
8	0	0	0	0	0	0	.15	0	0	0	.15	.15	0	.31	0	.15	0	0	0	0	0	0
9	0	0	0	.15	.15	0	0	.31	0	0	.15	0	0	0	0	.15	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	.15	.15	0	0	0	.15	0	0	.15	0	0	0	0
11	.15	0	0	0	0	0	0	.15	.31	0	.15	.31	0	0	0	0	.15	0	0	0	0	0
12	0	.15	0	0	.47	.15	0	0	0	.15	.47	.15	0	0	.15	0	0	0	0	0	0	0
13	.15	0	0	0	0	0	0	.31	.15	.15	0	.15	0	0	0	0	0	0	0	0	0	0
14	.31	.15	0	0	.15	0	.15	.47	0	0	.31	.31	0	0	0	0	0	0	0	0	0	0
15	.31	.31	.15	0	.15	.15	.15	0	.15	0	.47	.15	0	.15	0	0	0	0	0	0	0	0
16	.15	0	0	0	.15	.31	.15	.15	.15	.47	.62	.47	.47	0	.31	.15	0	0	0	0	0	0
17	0	.15	.15	0	.15	.15	.62	.15	.31	.31	.62	.31	0	0	.47	.31	0	0	0	0	0	0
18	.15	0	1.09	.15	0	.31	0	0	0	.15	.15	.15	.15	.15	.47	.15	0	0	0	0	0	0
19	0	0	5.60	13.67	0	7.78	7.52	0	0	.15	.62	.78	.47	.15	0	0	0	0	0	0	0	0
20	0	0	0	6.22	0	3.64	.84	.31	.15	.15	.78	.78	.15	.15	.15	0	0	0	0	0	0	0
21	0	0	0	.15	.15	.31	.15	0	.31	0	.31	0	.15	0	.15	.15	0	0	.15	0	0	0
22	0	0	0	.31	.15	.47	0	.15	.31	0	.62	0	0	0	0	.15	0	0	0	0	0	0
23	0	.15	0	0	0	.31	.15	0	0	0	.15	.15	.15	0	0	0	0	.15	0	0	0	0
24	0	.15	0	0	0	0	.62	.15	.31	.15	0	0	.31	0	.15	.47	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-29. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 11 10MPH TEST A2	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	.16	.32	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	.16	0	.32	.49	.98	.16	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	.16	.16	.16	.32	.65	1.63	1.31	.49	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	.16	0	.16	0	.16	.32	0	.16	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	.16	0	0	0	.49	.32	.32	.32	.16	.16	0	0	0
	7	0	0	0	0	0	0	0	0	0	.16	0	.16	0	0	.32	.16	0	.16	0	.16	0	0
	8	0	0	0	0	0	.16	.16	0	0	.32	0	0	.16	0	0	.49	.16	.16	0	0	0	0
	9	0	0	0	0	0	0	.16	.16	.16	0	0	.32	.65	.16	.16	0	.16	0	.16	0	0	0
	10	.16	0	0	0	0	0	.32	0	.16	.16	0	0	0	0	.16	0	0	0	0	0	0	0
	11	0	0	.16	0	0	0	.49	.16	0	0	0	0	0	.16	0	0	0	0	0	0	0	0
	12	.16	0	0	.16	.16	0	.16	.16	0	.16	0	0	.16	0	0	0	0	0	0	0	0	0
	13	0	0	0	.16	.16	0	0	0	0	0	0	.32	.32	.16	.65	0	0	0	0	0	0	0
	14	0	0	0	.16	0	0	0	.16	0	0	0	.49	0	.32	0	0	0	0	0	0	0	0
	15	0	0	0	0	.16	.16	.32	.16	.49	.16	0	.81	.16	0	.32	0	0	0	0	0	0	0
	16	0	0	.16	.32	0	0	.32	.65	.16	.16	.16	.65	.32	0	.32	0	0	0	0	0	0	0
	17	0	0	0	40.65	0	0	.32	1.63	.65	0	0	.98	0	0	.32	0	0	0	0	0	0	0
	18	0	0	0	6.88	0	.16	0	.65	.16	0	.32	.98	0	.16	1.63	0	0	0	0	0	0	0
	19	0	0	0	.16	.16	0	.16	.98	.16	.16	.16	.49	.32	0	.65	0	0	0	0	0	0	0
	20	0	0	0	0	.16	0	.16	.65	.32	0	.16	1.31	.16	.32	.32	0	0	0	0	0	0	0
	21	0	0	0	0	0	.49	.65	.32	0	.16	.16	0	.16	.16	.49	0	0	0	0	0	0	0
	22	0	0	0	0	0	.16	.32	.49	0	0	.32	.32	0	0	.32	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	.65	.16	.81	0	.32	0	.16	.32	.16	.16	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	.16	.49	.49	.49	.49	.32	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-30. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 km/h CYCLE

TRUCK 12 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	.46	.77	2.49	.46	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	.15	.77	.93	.46	1.09	2.80	1.71	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	.15	.31	0	0	0	.31	.15	0	0	0	0	0	0	0
4	0	0	.15	0	0	0	0	0	0	0	.15	.15	0	.15	.31	0	0	0	0	0	0	0
5	0	0	0	0	0	.15	0	.15	.15	.15	0	0	.15	.15	.31	0	0	0	0	0	0	0
6	0	0	0	0	.15	0	0	.15	0	0	.15	.15	0	.15	0	0	0	0	0	0	0	0
7	0	0	0	.15	0	0	0	0	0	0	.15	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	.15	.15	0	0	0	0	0	0	.15	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	.15	0	.15	0	0	.15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	.15	.15	0	0	0	.15	0	0	.15	0	.31	0	0	0	0	0	0	0
11	0	.15	0	0	0	.15	0	.15	.46	.15	0	0	.15	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	.15	0	.15	0	.15	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	.15	.15	.15	0	0	.15	0	.15	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	.15	.46	0	0	.15	.31	.15	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	.31	.31	.31	.15	.15	.31	.31	.31	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	.15	.31	0	0	.93	.46	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	.31	.15	.31	.15	0	.93	.93	.31	0	.15	0	0	0	0	0	0	0	0	0
18	0	0	.31	0	0	.15	.62	0	.15	.31	.15	0	0	0	0	0	0	0	0	0	0	0
19	0	0	17.91	0	.15	.15	.62	0	.15	.46	.15	.15	.31	0	0	0	0	0	0	0	0	0
20	0	0	30.57	.77	.62	.31	1.55	.31	0	.46	0	0	.15	0	0	0	0	0	0	0	0	0
21	0	0	0	1.09	.31	.77	1.09	.31	0	0	0	.15	0	0	0	0	0	0	0	0	0	0
22	0	0	0	.15	1.24	.46	.62	0	.15	.15	0	0	.15	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	.77	.77	.93	0	.15	.15	.15	.15	.15	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	.46	1.40	1.24	.62	.62	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-31. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 13 10MPH
TEST 62

VAC \ RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
√1	0	0	0	0	0	0	0	0	0	0	.15	.15	.77	.77	.62	1.08	1.08	.93	.77	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	.46	.15	.15	.15	.46	.15	.31	.15	0	0	0
3	0	0	0	0	0	0	0	0	.15	0	0	.31	.15	0	0	0	.15	.15	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	.15	0	0	0	.46	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	.15	0	0	.15	0	.15	.15	0	0	0	0	0
6	0	0	0	0	0	0	0	0	.15	0	0	.15	0	0	.31	0	0	0	0	0	0	0
7	0	0	0	0	0	0	.15	.15	0	0	0	.15	0	0	.15	.31	.15	0	0	0	0	0
8	0	0	0	0	.15	0	.15	0	0	0	.15	0	0	.15	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	.15	0	0	0	0	0	.15	0	0	.77	0	.15	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.15	0	1.08	0	0	0	0	0
11	0	0	0	0	0	0	.46	.15	0	0	0	.15	0	0	.15	0	.15	0	0	0	0	0
12	0	0	0	0	0	0	.15	.15	0	0	0	0	0	.15	0	0	0	.15	0	0	0	0
13	0	0	0	0	.15	.15	0	.15	0	.31	0	0	0	0	0	.31	0	0	0	0	0	0
14	0	0	0	0	0	.31	.15	0	0	0	0	0	0	.15	0	.31	.15	0	0	0	0	0
15	0	0	0	0	0	.15	.15	0	0	0	.93	0	.15	0	.15	.15	0	.46	0	0	0	0
16	0	0	0	.31	0	.31	.15	0	0	.15	.77	.15	.31	.15	.15	0	0	1.86	0	0	0	0
17	0	0	6.05	1.86	0	.31	.46	.31	.15	0	1.24	.31	1.24	0	0	.15	0	.15	0	0	0	0
18	0	0	2.21	37.42	0	.62	.93	0	0	.62	1.24	.15	.62	0	0	.15	0	0	0	0	0	0
19	0	0	0	2.21	0	1.24	.77	0	0	.93	.77	0	.15	0	0	0	0	0	0	0	0	0
20	0	0	0	0	.62	.46	0	0	0	.15	0	.31	0	0	.15	0	0	0	.15	0	0	0
21	0	0	0	0	.31	.77	.15	0	0	.15	.15	0	0	0	0	0	.15	0	0	0	0	0
22	0	0	0	0	0	.31	.93	.15	0	.31	.15	0	.15	0	.15	0	.15	.15	0	0	0	0
23	0	0	0	0	0	0	0	.62	.93	.62	.31	.15	0	.15	.15	.15	.15	.15	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	.31	.62	.31	.46	.62	.46	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-32. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 16 10MPH TEST 62	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	.31	1.24	3.11	1.24	2.33	1.71	.15	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	.15	.46	0	.31	.31	.15	.31	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	.31	.31	.15	0	.31	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	.15	.15	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	.31	0	0	0	.15	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	.15	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	.15	0	.15	.46	0	0	.15	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	.15	0	.15	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	.31	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	.15	0	0	.15	.15	.31	0	.15	.15	0	.15	0	0	0	0	0	0
	12	0	0	0	0	0	.31	.15	0	0	0	.15	.15	.15	0	.31	.15	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	0	.15	.15	0	.15	0	1.40	.15	0	0	0	0	0	0
	14	0	0	0	0	.15	0	0	.15	0	.15	.15	0	.15	.15	.15	0	0	0	0	0	0	0
	15	0	0	0	0	0	.15	0	0	0	.15	.15	0	.31	.62	.62	0	0	0	0	0	0	0
	16	0	0	0	.15	0	0	0	.15	0	1.09	0	0	.77	.77	.31	.15	0	0	0	0	0	0
	17	0	0	0	.31	0	0	0	0	0	.62	.31	.15	.46	.93	.15	0	0	0	0	0	0	0
	18	0	0	0	11.21	0	0	.15	0	0	2.05	0	.62	.93	.31	0	0	0	0	0	0	0	0
	19	0	0	0	35.20	0	.15	.46	.31	0	.62	0	0	2.49	.15	0	0	0	0	0	0	0	0
	20	0	0	0	.46	1.71	0	.15	0	0	.31	.15	.15	0	.31	0	0	0	0	0	0	0	0
	21	0	0	0	0	.46	.46	0	0	.15	.15	0	.15	0	.15	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	1.09	.31	0	0	0	.15	0	.46	.15	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	.93	.77	0	0	0	0	0	.15	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	.31	.62	.93	1.09	.31	0	.31	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	.31	.62	.62	.62	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 6-33. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 15 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	.82	1.31	1.48	.49	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	.16	.32	.16	.16	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.16	.16	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	.16	.65	.16	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	.16	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	.16	.16	0	.16	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	.16	.32	.16	0	0	0	0	0	0
9	0	0	0	0	0	0	0	.16	0	0	0	0	0	.82	.16	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	.16	0	0	0	.32	.16	.16	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	.16	0	0	.16	0	0	.16	.49	0	0	0	0	0	0
12	0	0	0	0	.16	0	.16	0	0	0	0	0	0	.65	.49	.82	0	0	0	0	0	0
13	0	0	0	0	0	.16	0	0	.16	0	0	0	.16	.32	0	.65	.16	0	0	0	0	0
14	0	0	0	0	0	.49	0	.16	0	0	0	0	.49	.65	0	.49	0	0	0	0	0	0
15	0	0	0	0	.16	.16	0	0	.16	0	.16	.32	.16	.65	.82	.16	.16	0	0	0	0	0
16	0	0	.16	.16	.16	.16	0	0	0	.16	.16	.32	.65	0	.49	.32	0	0	0	0	0	0
17	0	0	.49	.49	0	0	0	.16	0	0	0	.16	.16	0	0	3.12	0	0	0	0	0	0
18	0	0	7.23	5.75	0	0	0	0	0	.16	.16	1.15	1.48	.16	.32	.16	0	0	0	0	0	0
19	0	0	.98	33.38	0	0	0	0	0	.16	.16	.98	1.97	.32	0	.16	0	0	0	0	0	0
20	0	0	0	.32	0	0	0	0	0	.49	.98	2.46	.82	0	.16	.65	0	0	0	0	0	0
21	0	0	0	.49	.65	.16	0	0	0	0	.32	.32	.32	.16	.49	.16	0	0	0	0	0	0
22	0	0	0	0	0	.16	0	0	0	0	.32	.16	.16	.16	.32	0	0	0	0	0	0	0
23	0	0	0	0	0	.16	.16	.32	0	.16	0	0	0	.32	.32	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	.65	.16	.82	.49	.16	.49	.32	.65	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	.16	.82	.65	.65	.16	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-34. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 16 10MPH TEST 62	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	.82	.32	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	.16	.65	1.31	.98	.98	0	0	0	0	0	0
	3	0	0	0	0	.16	0	.16	0	0	0	0	0	0	0	0	.16	.16	0	0	0	0	0
	4	0	0	0	0	0	0	0	.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	.16	0	0	0	.16	0	0	.16	.32	.16	0	0	0	0	0	0	0	0
	6	0	0	0	0	.16	0	0	0	0	0	.16	0	.16	0	.32	.32	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	.16	.32	.16	.32	0	0	0	0	0	0
	8	0	0	0	0	.16	.32	0	0	0	0	0	.49	.16	.32	.16	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	.16	0	0	.16	.32	0	0	0	0	0	0	0
	10	0	0	0	0	.16	0	0	0	0	0	0	0	.49	.49	.16	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	.16	.16	.16	.16	.16	0	.16	0	0	0	0	0
	12	0	0	0	0	.16	.16	0	0	0	0	.16	.32	0	0	.65	0	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	.16	0	.16	0	.49	0	.49	0	0	0	0	0	0	0
	14	0	0	0	0	.16	.16	.49	0	.16	0	0	.32	.65	.16	.65	.32	0	0	0	0	0	0
	15	0	0	0	.16	0	.16	0	0	0	.32	.65	0	0	0	.16	1.31	0	0	0	0	0	0
	16	0	0	0	20.98	0	0	0	0	0	0	.16	.16	.49	.16	.49	1.15	0	0	0	0	0	0
	17	0	0	0	27.08	.32	0	0	.49	0	.16	.49	1.31	1.31	.32	.32	0	0	0	0	0	0	0
	18	0	0	0	.49	.82	0	0	.16	0	.49	.65	0	1.47	.16	.49	.16	0	0	0	0	0	0
	19	0	0	0	0	.49	.16	3.28	.49	0	.32	.49	0	.49	0	.32	0	0	0	0	0	0	0
	20	0	0	0	0	0	.65	.98	.82	0	0	.65	.32	.65	.32	.16	0	0	0	0	0	0	0
	21	0	0	0	0	0	.16	.49	.16	.16	.49	.49	.82	.49	.16	.16	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	.32	.49	.49	.32	.65	.32	.82	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-35. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 17 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	.17	.35	.70	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	.17	0	0	0	.35	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	.17	0	0	.17	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	.17	0	0	.53	.17	0	.17	0	.17	.17	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	.35	.17	.35	.17	.17	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	.17	0	.17	0	0	.35	.35	0	0	0	0	0	0	0	0
7	0	0	0	.17	0	0	0	0	0	.17	0	.17	.17	.17	0	0	0	0	0	0	0	0
8	0	0	0	0	.17	0	0	0	.17	.17	0	0	.35	.53	0	.17	0	0	0	0	0	0
9	0	0	0	.17	0	0	.17	0	0	.17	0	.17	.17	.17	.17	0	.17	0	0	0	0	0
10	0	0	0	0	0	0	0	0	.17	.17	.17	0	0	.53	.17	.17	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	.17	0	.17	.35	0	0	.35	0	0	0	0	0	0	0
12	0	0	0	0	.17	0	0	0	.17	0	.17	.17	.17	.88	0	.17	.17	0	0	0	0	0
13	0	0	0	0	0	.35	0	0	.17	.17	.35	.17	1.23	.53	0	.17	0	0	0	0	0	0
14	0	0	0	.17	.17	.35	.17	.35	.35	.17	.88	1.06	1.06	.53	.17	0	0	0	0	0	0	0
15	0	0	.17	.17	.17	0	.53	.17	.35	.35	.17	.88	0	0	0	0	0	0	0	0	0	0
16	0	0	.17	0	.17	0	0	0	.88	0	0	.17	.17	.17	.17	0	.17	0	0	0	0	0
17	0	0	.35	0	0	.17	.17	0	.35	.17	0	1.41	0	.17	.35	0	.17	0	0	0	0	0
18	0	0	17.69	0	0	.35	.17	0	.70	.17	0	.70	0	.17	0	0	0	0	0	0	0	0
19	0	0	25.64	.17	0	.17	0	0	.35	0	.53	2.12	0	0	.17	0	.17	0	0	0	0	0
20	0	0	.17	.70	0	1.23	0	0	.70	0	0	.70	0	0	0	0	.17	0	0	0	0	0
21	0	0	0	.53	0	.70	.17	0	.17	.17	.17	.35	0	0	0	.35	0	0	0	0	0	0
22	0	0	0	.35	.17	0	0	0	0	0	0	0	.17	0	.17	.17	0	0	0	0	0	0
23	0	0	0	0	.17	0	0	0	0	0	0	.17	0	.17	.17	.17	0	0	0	0	0	0
24	0	0	0	0	0	1.06	0	0	.70	0	.53	.53	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	.17	1.23	1.41	1.41	1.94	.70	.17	.35	.17	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	.17	.17	.53	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-36. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 17 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	.35	.88	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	.17	0	0	.17	.35	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	.17	0	0	.17	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	.35	.17	0	.17	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	.17	.35	.17	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	.17	.53	.17	0	.17	.17	0	.17	0	0	0	0	0	0
7	0	0	0	0	0	0	0	.17	0	.17	.17	0	.17	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	.35	0	.17	.35	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	.35	0	.17	0	0	0	.53	.17	.17	0	0	0	0	0	0	0
10	0	0	0	.17	0	0	0	0	0	0	.17	.53	.17	.35	0	0	0	0	0	0	0	0
11	0	0	0	.35	.17	.17	0	0	0	0	.53	0	0	.17	.35	.17	0	0	0	0	0	0
12	0	0	0	.17	.17	.17	0	0	.53	0	0	.17	.17	.88	0	0	0	0	0	0	0	0
13	0	0	0	.17	.17	.17	0	.53	0	.53	.17	.70	0	.53	.17	.17	0	0	0	0	0	0
14	0	0	0	0	.17	.17	.17	.17	.35	.70	.35	1.76	.35	.17	0	.17	0	0	0	0	0	0
15	0	0	0	0	0	0	.35	.17	.70	.53	.17	.35	0	.17	0	0	0	0	0	0	0	0
16	0	0	0	.17	.35	0	.35	.17	.35	.35	.70	.17	.17	.70	0	0	0	0	0	0	0	0
17	0	0	.53	0	0	0	0	.17	.35	0	.70	.17	.17	.17	0	0	0	0	0	0	0	0
18	0	0	14.51	.17	.35	.17	0	.17	.17	0	2.82	.35	0	.17	.17	.35	0	0	0	0	0	0
19	0	0	15.00	0	0	.35	0	.17	.17	0	1.06	.17	0	.17	0	0	0	0	0	0	0	0
20	0	0	13.67	0	.17	.53	0	0	.70	0	.53	0	.17	0	0	.17	0	0	0	0	0	0
21	0	0	0	.53	0	.53	0	.53	.35	.17	.53	0	0	0	0	.17	0	0	0	0	0	0
22	0	0	0	.17	.35	0	0	0	.35	0	.35	0	.17	0	0	0	0	0	0	0	0	0
23	0	0	0	0	.35	.35	0	.17	0	0	.35	0	0	.17	.17	0	0	0	0	0	0	0
24	0	0	0	0	.53	.70	.17	.17	0	.35	.35	0	.17	.17	0	0	0	0	0	0	0	0
25	0	0	0	0	0	.70	1.23	1.41	1.06	.53	.35	0	.35	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	.53	.35	.53	.53	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-17. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 17 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	.52	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	.34	.34	.17	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	.17	.17	0	.34	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	.17	0	.17	0	0	.17	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	.17	0	0	0	0	0	.17	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	.17	.17	0	.17	.34	0	.17	.17	0	0	0	0	0
8	0	0	0	0	0	0	.17	0	.17	0	.17	0	.17	.17	.17	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	.17	0	.17	.52	0	0	.52	0	.17	0	0	0	0	0
10	0	0	0	.17	0	.17	.17	0	0	0	0	.17	.17	0	.34	.34	0	.17	0	0	0	0
11	0	0	0	0	.34	0	.17	.17	.34	.17	0	0	.17	0	.52	.17	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	.17	.34	0	.34	1.86	0	0	0	0	0	0	0
13	0	0	0	.17	.34	0	.34	0	.17	.34	0	.34	2.25	0	.69	0	0	.17	0	0	0	0
14	0	0	0	0	.17	.34	0	.17	0	.17	.52	.52	0	0	.69	0	0	0	0	0	0	0
15	0	0	.17	.34	0	0	0	0	0	.17	0	.86	.52	0	.34	0	0	0	0	0	0	0
16	0	0	0	0	0	.17	0	0	.17	0	0	.86	.34	0	.34	0	.17	.17	0	0	0	0
17	0	0	3.47	0	0	.52	0	0	.52	0	.17	.86	.52	0	.52	0	0	0	0	0	0	0
18	0	0	13.19	0	.17	.17	0	0	.34	.52	0	.52	1.04	0	0	0	.17	0	0	0	0	0
19	0	0	28.79	0	.17	.17	.34	0	.69	.34	.17	.52	.86	0	.17	0	.17	0	0	0	0	0
20	0	0	.52	.52	.17	.52	0	0	.34	0	.17	.52	0	.17	.17	0	0	0	0	0	0	0
21	0	0	0	.17	.34	.86	.34	0	.17	.34	.17	0	.34	0	.34	.17	0	0	0	0	0	0
22	0	0	0	0	.69	.52	.17	0	.52	0	0	.34	.34	0	.17	0	.34	0	0	0	0	0
23	0	0	0	0	.34	.17	.17	0	.17	0	.34	.34	.34	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	.17	1.04	.34	.17	.17	.52	.52	.17	.17	.17	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	.69	1.04	1.56	.86	.52	.17	.34	.17	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-30. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 18 10MPH TEST 62	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	.15	0	0	0	0	0	0	0	.46	.77	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	.15	0	0	0	0	.46	.15	1.40	3.11	2.80	1.24	0	0	0	0	0
	3	0	0	0	0	0	0	.15	0	0	.15	.31	0	.15	0	.15	0	.93	0	0	0	0	0
	4	0	0	0	0	.15	0	0	0	.15	0	.15	.15	.31	.15	.15	.31	.46	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	.15	.15	.15	.15	.15	.31	.15	0	0	0	0	0
	6	0	0	0	.31	.15	0	0	0	0	0	0	0	0	.15	0	0	.15	0	0	0	0	0
	7	0	0	0	0	.15	.15	0	.15	0	.15	.31	.15	0	0	0	0	0	.15	0	0	0	0
	8	0	0	0	0	0	.15	0	0	.15	0	.31	0	.15	0	.15	.15	.15	0	0	0	0	0
	9	0	0	0	.15	0	0	0	0	0	0	0	.15	0	0	.31	0	.15	.15	0	0	0	0
	10	0	0	0	0	0	0	0	.15	0	0	0	.15	.15	.15	.15	.15	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	.15	.15	0	0	.15	0	0	.15	0	0	0	0
	12	0	0	0	0	.15	.15	0	0	0	.15	.31	0	.31	0	.15	0	0	.15	0	0	0	0
	13	0	0	0	0	.15	.15	0	0	0	0	.31	.15	.31	.15	0	0	.15	.31	0	0	0	0
	14	0	0	0	0	.15	0	.15	0	0	0	.77	.15	.31	.15	0	.15	.46	0	0	0	0	0
	15	0	0	0	0	0	0	0	.15	0	0	.46	0	.31	.77	0	.15	.15	0	0	0	0	0
	16	0	0	0	0	0	.15	0	.15	0	0	.77	0	.62	.15	0	0	0	0	0	0	0	0
	17	0	0	0	.15	0	0	.15	0	0	0	0	0	.46	2.64	0	.31	0	0	0	0	0	0
	18	0	0	0	.31	0	.15	.31	.15	0	0	0	0	.46	0	0	0	0	0	0	0	0	0
	19	0	0	0	46.89	0	.15	.31	0	0	0	.15	.15	0	.46	.15	0	.15	0	0	0	0	0
	20	0	0	0	1.71	0	.46	1.71	.15	0	0	.15	0	0	0	.15	0	0	0	0	0	0	0
	21	0	0	0	.15	.15	.15	.62	0	0	0	0	0	0	.31	0	0	0	0	0	0	0	0
	22	0	0	0	0	1.09	.31	.46	0	0	.31	0	0	.15	.15	.15	0	0	0	0	0	0	0
	23	0	0	0	0	0	.62	.31	0	0	0	0	.15	0	.15	.15	.15	0	0	0	0	0	0
	24	0	0	0	0	0	0	.46	.77	.93	.62	0	.31	.15	0	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	.15	.93	.46	.31	.15	.15	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 9-17. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 18 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	.15	0	0	.15	0	0	.15	0	0	0	0	0	0	0	0	0
2	0	0	0	0	.15	0	0	0	.15	0	0	.15	.15	1.06	1.01	1.06	1.21	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	.15	.30	.15	.75	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	.30	.15	.15	.30	.15	.15	0	.15	0	0	0	0
5	0	0	0	0	.15	0	0	0	0	0	0	.15	.30	0	.15	.15	0	0	0	0	0	0
6	0	0	0	0	.15	0	0	0	0	0	0	0	0	.15	0	0	.30	0	0	0	0	0
7	0	0	0	.15	0	0	.15	0	0	.15	0	0	.15	.90	.30	.45	0	.15	0	0	0	0
8	0	0	0	0	0	0	.15	0	0	.15	0	0	.15	.60	.15	0	0	0	0	0	0	0
9	0	0	0	0	0	.15	0	0	0	0	.15	.15	.15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	.15	0	0	0	.45	.30	.60	0	0	0	0	0	0	0	0
11	0	0	0	0	0	.15	0	0	.15	0	.30	0	0	.15	.30	0	0	0	0	0	0	0
12	0	0	0	0	.15	.15	0	0	0	0	.45	0	.15	.15	.45	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	.15	.45	0	.60	0	.75	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	.15	0	0	.60	0	1.36	.45	.15	.15	0	0	0	0	0	0
15	0	0	0	0	0	0	.15	0	0	0	.45	0	1.36	1.21	.75	.15	0	0	0	0	0	0
16	0	0	0	0	.30	0	.30	0	0	0	1.51	0	2.57	.60	.30	0	0	0	0	0	0	0
17	0	0	0	.15	0	.15	.30	0	0	0	.45	.15	2.27	.60	.15	0	0	0	0	0	0	0
18	0	0	0	0	0	.15	.30	0	0	0	1.06	0	.15	0	0	0	0	0	0	0	0	0
19	0	0	0	[illegible]	0	.45	3.33	0	0	0	.15	0	.30	.15	0	0	0	0	0	0	0	0
20	0	0	0	1.06	0	.45	1.51	0	0	.15	.15	0	0	.15	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	.30	0	0	0	0	.15	.15	0	0	0	0	0	0	0	0	0
22	0	0	0	0	.60	0	.15	0	0	0	.15	.15	.15	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	.30	.15	.30	0	0	.30	0	.30	.15	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	.15	.45	.75	.60	.30	.30	.15	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	.30	.30	.90	.30	.15	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-41. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 16 kph CYCLE

TRUCK 10 10MPH
TEST 62

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	.31	.46	.31	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	.15	.46	.62	1.24	1.86	2.18	1.71	.15	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	.15	.15	.15	.31	.15	.31	.31	.15	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	.15	.15	0	.31	0	0	0	0	0
5	0	0	0	0	.15	0	.15	0	.15	0	0	0	.15	.15	.15	0	.15	.15	.15	0	0	0
6	0	0	0	0	0	0	0	0	0	0	.15	.15	0	0	0	0	0	0	.15	0	0	0
7	0	0	0	0	0	.15	.15	0	0	0	0	.31	0	.15	.15	.15	0	0	0	0	0	0
8	0	0	0	0	0	.31	.15	0	0	0	.15	.15	.15	.15	.15	.15	.15	.15	0	0	0	0
9	0	0	0	0	0	.15	0	0	0	0	0	.15	.15	0	0	0	0	0	.15	0	0	0
10	0	0	0	0	0	0	.15	0	.15	.15	0	.15	0	0	0	.15	0	0	0	0	0	0
11	0	0	0	0	0	0	0	.15	0	0	0	.46	.15	.46	0	.31	.15	.15	.31	0	0	0
12	0	0	0	0	0	0	.31	.15	0	0	0	.31	.15	.46	0	0	.15	0	.15	0	0	0
13	0	0	0	0	0	.15	0	.15	0	0	0	.93	0	.31	0	.15	0	.15	.93	0	0	0
14	0	0	0	0	0	.15	.15	.31	0	0	.46	.15	0	.15	.31	.15	0	0	0	.15	0	0
15	0	0	0	0	.15	0	.15	.15	0	.15	.15	0	.15	.15	.62	.31	.15	0	.15	.31	0	0
16	0	0	0	0	.31	0	.15	.15	0	.15	.77	0	.15	2.69	.15	0	.15	0	.31	0	0	0
17	0	0	0	.31	.15	0	0	0	0	0	0	.15	1.09	.15	.15	0	0	0	0	0	0	0
18	0	0	0	12.97	.15	0	.15	.31	0	0	0	0	.15	0	0	.15	.15	0	0	0	0	0
19	0	0	0	39.04	0	0	2.24	.15	0	0	0	0	.31	0	.15	0	0	0	0	0	0	0
20	0	0	0	.31	.62	0	.93	.31	0	0	0	0	.15	.15	.15	0	0	.15	0	0	0	0
21	0	0	0	0	.46	0	.62	0	0	0	.15	0	.15	0	.31	0	0	0	0	0	0	0
22	0	0	0	0	.15	1.09	0	0	0	0	.31	0	0	0	.15	0	0	0	0	0	0	0
23	0	0	0	0	0	0	.46	.62	0	0	0	0	0	.15	0	.15	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	.46	1.39	.77	.62	.31	.46	0	.31	.15	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	.15	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 9-43. PERCENT TIME IN NON-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 1 20MPH
TEST 66

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	.16	.50	.33	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	.16	.50	.33	.16	.33	1.16	0	.50	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	.16	.50	1.00	.66	3.00	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	.33	.33	.33	.50	0	.16	.66	2.00	0	0	0	0	0	0
6	0	0	0	0	0	0	0	.16	.16	0	.50	.50	0	.16	.33	.16	0	0	0	0	0	0
7	0	0	0	0	0	.16	0	.16	0	.16	.16	.66	0	.16	.50	.16	0	0	0	0	0	0
8	0	0	0	0	0	0	.16	0	.16	0	.16	0	.16	.50	1.50	0	0	0	0	0	0	0
9	0	0	0	0	0	0	.16	.16	0	.16	.83	.16	0	.33	.66	0	0	0	0	0	0	0
10	0	0	0	.16	.16	.16	.33	.16	.33	.33	0	.16	1.00	1.50	.16	0	0	0	0	0	0	0
11	0	0	0	0	.16	.16	0	0	0	0	.16	.83	1.00	0	.66	.16	0	0	0	0	0	0
12	0	0	0	.16	0	.16	.16	.16	0	.16	0	1.00	.33	0	0	.16	0	0	0	0	0	0
13	0	0	0	0	.16	0	0	0	.33	0	1.66	.50	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	.16	.16	1.00	.16	.16	1.00	.33	.16	0	.16	0	0	0	0	0	0	0
15	0	0	0	0	.33	.33	0	.16	.50	.16	.83	.16	.16	.16	.83	.16	0	0	0	0	0	0
16	0	0	0	0	.33	.16	.16	.50	.50	.83	.16	.16	.33	0	.83	0	0	0	0	0	0	0
17	0	0	0	0	1.16	.16	.33	1.33	.16	.33	0	.16	1.00	.16	0	0	0	0	0	0	0	0
18	0	0	0	0	.50	.16	.16	.33	0	.16	.33	0	0	0	.50	0	0	0	0	0	0	0
19	0	0	0	.16	.66	.50	.66	.33	.16	.33	0	.16	0	0	0	0	0	0	0	0	0	0
20	0	0	.16	.16	.83	0	.50	.16	.33	0	0	.16	.16	.33	0	0	0	0	0	0	0	0
21	0	0	2.16	29.50	.50	.16	.33	.16	.16	.16	.33	.33	0	.16	0	0	0	0	0	0	0	0
22	0	0	0	.83	1.00	.16	.16	.16	0	0	.16	.16	.33	0	0	0	0	0	0	0	0	0
23	0	0	0	0	1.00	1.33	1.66	1.16	.66	.50	.66	.16	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE D-42. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 2 20MPH
-TEST 44

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	.81	.97	.32	.48	.81	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	.16	.32	.16	.32	0	.16	0	0	0	0	0	0	0
3	0	0	0	0	.16	0	0	0	0	.16	.16	0	.16	.32	0	0	0	0	0	0	0	0
4	0	0	.16	0	0	0	0	.32	.32	.16	.48	.32	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	.16	.32	.48	.16	.32	0	.65	.32	.16	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	.16	.16	0	.16	.16	.32	.16	0	1.14	0	0	0	0	0	0	0
7	0	0	0	0	.32	0	0	0	.16	.16	.16	1.14	.16	.48	.32	0	0	0	0	0	0	0
8	0	0	0	0	0	.16	0	.16	0	0	.32	.16	.32	.32	2.76	0	0	0	0	0	0	0
9	0	0	0	0	0	.32	.32	0	.16	.16	.48	.97	.16	1.14	.48	0	0	0	0	0	0	0
10	0	0	0	0	.16	.16	.16	.16	0	0	.48	.81	0	1.46	.16	0	0	0	0	0	0	0
11	0	0	0	0	0	0	.16	0	0	.32	.48	2.76	.48	.16	.32	0	0	0	0	0	0	0
12	0	0	0	0	.16	.16	0	0	.16	.48	.81	0	.48	0	0	.16	0	0	0	0	0	0
13	0	0	0	0	.32	0	.16	0	0	1.14	1.62	0	.65	.16	.32	.32	0	0	0	0	0	0
14	0	0	0	0	0	.16	0	0	0	.16	1.30	0	.32	0	0	.16	0	0	0	0	0	0
15	0	0	0	0	.65	.32	0	.16	0	.81	.16	0	.16	.32	.81	.16	0	0	0	0	0	0
16	0	0	0	0	.81	0	0	.16	0	.16	.16	.16	.16	0	.97	.16	0	0	0	0	0	0
17	0	0	0	5.84	1.79	0	.48	.32	.16	1.14	0	.16	2.27	.16	.32	0	0	0	0	0	0	0
18	0	0	0	19.21	.48	0	.32	.16	.32	.32	.16	0	1.14	.32	0	0	0	0	0	0	0	0
19	0	0	0	0	.81	0	.16	0	.65	.97	.16	0	1.30	0	.16	0	0	0	0	0	0	0
20	0	0	0	0	.81	.16	.16	.16	.16	.16	.16	0	.32	.48	0	0	0	0	0	0	0	0
21	0	0	0	0	.16	.65	.65	.32	.16	0	0	.16	.32	.16	.16	0	0	0	0	0	0	0
22	0	0	0	0	0	.16	.65	.81	0	0	0	.48	.16	.16	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	.32	.97	.97	1.14	.65	.32	.32	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	.16	.16	.16	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 9-43. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 3 20MPH
TEST A4

VAC \ RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	.48	1.92	2.41	.48	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	.16	0	.16	.32	.64	1.44	1.28	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	.16	.16	.32	0	.32	.32	.32	0	0	0	0	0	0	0	0
4	0	0	.16	0	0	0	0	0	.16	.16	0	.32	.16	.16	0	0	0	0	0	0	0	0
5	0	0	0	0	.16	0	0	.16	.16	.16	.32	.32	.16	.16	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	.16	0	.16	0	.16	3.21	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	.16	.32	0	0	0	.64	.16	.16	0	0	0	0	0	0	0	0
8	0	0	0	.16	0	.16	.16	0	.48	.16	.16	.64	1.92	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	.16	.32	.64	.80	1.28	.16	.16	0	0	.16	0	0	0	0
10	0	0	0	0	0	0	0	0	.16	.16	0	1.60	0	.48	0	0	0	0	0	0	0	0
11	0	0	0	0	0	.32	0	0	.32	.64	.32	1.12	.16	.16	0	0	.16	0	0	0	0	0
12	0	0	0	0	0	0	0	0	1.44	.96	0	.48	.16	0	.16	0	0	0	.16	0	0	0
13	0	0	0	0	.16	0	0	.16	.96	0	.16	0	.16	0	0	.32	0	0	0	0	0	0
14	0	0	0	0	0	.48	0	.16	.80	.48	.16	.80	.16	0	.16	0	0	0	.16	0	0	0
15	0	0	0	0	.16	0	0	.16	.16	.64	0	.48	.16	.16	0	.48	0	.16	.64	0	0	0
16	0	0	0	0	0	.16	.48	0	.16	.48	.16	1.12	0	.16	.16	.32	0	0	.64	0	0	0
17	0	0	0	0	.16	.48	0	.32	.48	.64	.16	.32	.32	.16	.48	.80	0	0	0	0	0	0
18	0	0	0	.48	0	.32	.48	0	.16	.64	0	.16	0	.16	.64	.16	0	0	0	0	0	0
19	0	0	0	25.60	.64	.64	.80	.16	.16	.32	.16	.16	0	0	0	0	0	.16	0	0	0	0
20	0	0	0	1.12	0	.32	.16	0	0	0	.16	0	.32	0	.16	0	0	0	0	0	0	0
21	0	0	0	0	.80	.64	.32	.32	.48	.32	0	0	0	.16	.16	0	0	0	0	0	0	0
22	0	0	0	0	.48	.64	.32	.32	.16	.32	.32	.16	.16	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	.64	1.28	1.60	1.12	.16	.16	.32	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	.32	.16	1.28	.48	.16	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 9-44. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK A 20MPH
TEST 44

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	.64	1.28	1.76	1.44	1.12	.16	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	.16	0	0	.16	0	.16	.16	1.12	.64	0	0	0	0	0	0	0
3	0	0	0	.16	.48	0	0	.16	.16	.48	.16	.16	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	.16	0	.32	.48	.16	.32	.16	.16	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	.16	.64	.16	.48	.32	.32	.80	0	0	0	0	0	0	0
6	0	0	0	0	.16	0	0	0	.16	0	0	.16	.48	.32	2.61	0	0	0	0	0	0	0
7	0	0	0	0	.16	0	0	.48	.16	.16	0	.48	.48	.64	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	.32	.32	.96	.96	.96	.16	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	.32	.16	.32	0	1.28	0	.32	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	.32	.16	.16	.32	.64	1.28	0	.16	0	0	0	0	0	0	0	0
11	0	0	0	0	0	.32	.32	0	.32	1.60	1.60	.32	.16	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	.32	0	0	.48	1.60	.32	0	0	.16	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	.16	0	.48	1.28	.16	0	0	.16	0	0	0	0	0	0	0	0
14	0	0	0	0	0	.32	0	0	.64	.32	.64	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	.32	0	.32	0	.48	.32	0	.16	.96	0	0	0	0	0	0	0	0
16	0	0	0	0	.64	0	0	.32	0	.64	.32	.16	.32	.64	0	0	0	0	0	0	0	0
17	0	0	0	.16	.96	.64	0	0	0	.64	.64	0	.16	.80	0	0	0	0	0	0	0	0
18	0	0	0	16.77	.64	1.12	.16	.16	.16	0	.32	0	0	.48	0	0	0	0	0	0	0	0
19	0	0	0	4.18	3.37	.96	.48	.48	0	.32	0	0	.16	.32	0	0	0	0	0	0	0	0
20	0	0	0	0	.80	.96	.96	1.60	.32	.32	.16	0	.48	.32	0	0	0	0	0	0	0	0
21	0	0	0	0	0	.80	.16	2.61	1.60	1.28	.64	.32	.32	.32	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	.48	.96	0	.48	.16	.96	.80	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-45. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 5 20MPH
TEST 64

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	.17	0	0	0	.69	2.76	2.24	.34	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	.34	.17	0	0	1.03	1.90	2.76	2.76	.69	0	0	0	0	0	0	0
3	0	0	0	.17	0	0	0	0	.17	.17	.34	.17	.17	.17	.86	1.73	2.24	2.94	0	0	0	0
4	0	0	0	0	0	0	.17	.17	.17	.17	0	0	0	.17	.34	.17	0	.34	0	0	0	0
5	0	0	0	0	0	0	0	0	.17	.51	0	.69	.17	0	.17	.34	.17	.17	0	0	0	0
6	0	0	0	0	0	0	.17	0	0	0	0	.34	.17	.34	.17	0	0	.17	0	0	0	0
7	0	0	0	0	0	0	.17	0	.17	.17	0	0	0	0	.34	.34	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	.17	0	.17	0	0	0	.69	.69	.17	0	0	0	0	0
9	0	0	0	0	0	.17	.17	0	.17	0	0	.17	.17	0	.34	.51	0	0	0	0	0	0
10	0	0	0	.17	0	0	0	.17	0	0	0	.69	.17	0	1.21	.34	0	0	0	0	0	0
11	0	0	0	0	0	.34	0	0	0	.17	.17	0	.17	0	0	.17	0	0	0	0	0	0
12	0	0	0	0	0	.51	0	0	0	0	.17	.34	.17	0	0	0	0	.17	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	.34	.17	0	0	.34	0	0	0	0	0	0
14	0	0	.86	0	0	.51	0	.69	0	.17	0	.17	.17	0	0	0	0	0	0	0	0	0
15	0	0	2.59	0	0	.34	.17	1.03	0	.69	.51	.34	.17	.34	0	.17	0	.17	0	0	0	0
16	0	0	12.97	0	0	.51	.34	0	0	0	.34	.34	0	.17	0	.17	0	0	0	0	0	0
17	0	0	10.72	.51	0	.51	.34	0	.17	0	0	.17	0	0	0	0	.17	0	0	0	0	0
18	0	0	.17	0	0	.69	.17	0	0	0	.51	.17	.17	.34	0	.17	.34	0	0	0	0	0
19	0	0	0	0	.34	.34	0	0	0	0	0	0	.17	0	.17	0	.34	0	0	0	0	0
20	0	0	0	.34	.17	.69	.17	.51	0	.17	0	0	0	.34	0	.17	.17	0	0	0	0	0
21	0	0	0	0	.51	.34	0	.34	.34	0	0	0	.34	0	0	.17	.17	0	0	0	0	0
22	0	0	0	0	.34	1.03	1.21	1.03	.34	0	0	0	.17	0	.17	.17	0	0	0	0	0	0
23	0	0	0	0	0	0	.51	1.73	1.21	.17	.17	0	.17	.17	.17	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	.17	.34	.51	1.21	.34	.34	.34	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	.17	.17	.17	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE D-46. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 6 20MPH
TEST 64

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	.31	1.27	.31	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	.15	.31	.95	.95	.79	.79	1.63	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	.15	0	0	.31	.15	.31	.15	.15	0	0	0	0	0	0	0	0
4	0	0	0	0	0	.15	0	0	.15	.47	.15	.15	.47	.47	0	0	0	0	0	0	0	0
5	0	0	0	.15	0	.15	0	0	0	.15	.63	.31	.15	.79	0	0	0	0	0	0	0	0
6	0	0	0	.15	0	0	0	0	0	.31	0	0	.15	.63	0	0	0	0	0	0	0	0
7	0	0	0	0	0	.15	.15	0	0	.15	.31	0	.95	.79	0	0	0	0	0	0	0	0
8	0	0	0	0	0	.15	0	.15	.31	.47	.15	.47	.79	.79	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	.31	0	.31	.15	1.27	1.75	.79	0	0	0	0	0	0	0	0
10	0	0	0	0	.15	0	0	0	.79	.15	.79	1.59	.47	.15	.15	0	0	0	0	0	0	0
11	0	0	0	0	0	0	.31	.15	.95	.31	.47	.63	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	.15	.15	0	.31	.15	.79	1.27	.31	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	.47	0	.15	.31	.15	.79	.15	.15	0	0	0	0	0	0	0	0
14	0	0	0	.15	.15	0	.15	.15	.79	.15	.47	.31	.15	.15	.15	.15	0	0	0	0	0	0
15	0	0	0	.31	0	0	.15	0	0	0	0	.79	0	0	.47	0	0	0	0	0	0	0
16	0	0	0	3.18	.15	.79	.63	.15	.15	.15	.15	.63	0	0	.15	.15	0	0	0	0	0	0
17	0	0	0	11.78	.31	.63	.15	0	.15	.47	0	.63	.31	0	0	.79	0	0	0	0	0	0
18	0	0	0	8.59	.79	1.59	.15	0	.15	1.75	0	.63	.15	.15	.79	.79	0	0	0	0	0	0
19	0	0	0	.79	1.91	.79	.15	0	.15	.15	0	.63	.15	0	.15	.15	0	0	0	0	0	0
20	0	0	0	0	.15	1.27	.15	0	0	0	.31	.15	0	.15	0	0	0	0	0	0	0	0
21	0	0	0	0	0	2.22	.15	.15	.31	0	.15	0	.31	0	.15	0	0	0	0	0	0	0
22	0	0	0	0	0	0	1.27	.79	.15	.47	.31	0	0	.31	.15	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	.31	1.63	1.59	1.11	0	.31	.15	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	.47	.47	.31	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-47. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 7 20MPH
TEST 44

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	.16	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	1.60	2.09	.96	1.12	1.12	.32	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	.16	0	.80	.32	.32	.32	0	.16	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	.16	.64	0	.32	.16	.16	.64	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	.16	.16	.16	.64	0	0	0	0	0
6	0	0	0	0	.16	0	0	0	0	.16	.32	.48	.48	.32	.16	.16	1.28	0	0	0	0	0
7	0	0	0	0	.32	0	0	0	0	.32	.32	.16	.32	.96	1.12	.32	1.12	0	0	0	0	0
8	0	0	0	0	.16	.16	0	0	.16	0	.80	.32	0	1.44	.96	0	.48	.32	0	0	0	0
9	0	0	0	0	.16	.16	0	.16	0	.16	.48	.48	0	2.09	.80	.16	0	0	.16	0	0	0
10	0	0	0	.16	0	0	0	.16	.16	0	.32	.48	.16	.16	.48	.16	0	0	0	0	0	0
11	0	0	0	0	.16	0	.16	.16	.64	.16	.16	.48	0	.16	.16	0	.16	0	0	0	0	0
12	0	0	0	0	0	0	.32	.16	.32	0	1.28	1.12	.48	0	.16	.16	0	.16	0	0	0	0
13	0	0	0	0	.16	.16	0	.16	0	0	.80	.16	1.76	.16	.16	.16	.32	.32	0	0	0	0
14	0	0	0	0	0	.16	0	.32	0	.16	.64	.48	.32	0	.32	0	0	.16	0	0	0	0
15	0	0	0	0	0	0	0	.64	0	0	.80	0	0	0	.64	0	0	.48	0	0	0	0
16	0	0	0	0	0	0	0	.48	0	0	.32	0	.32	.16	.16	0	.16	.64	0	0	0	0
17	0	0	0	.32	0	.16	.32	.32	0	0	.48	0	.16	.16	.32	0	0	1.28	0	0	0	0
18	0	0	0	29.56	0	.64	.96	.16	0	0	.32	.32	0	.32	.32	0	0	.32	0	0	0	0
19	0	0	0	.16	.16	0	.96	.48	.16	0	0	0	0	.16	0	.16	.32	0	0	0	0	0
20	0	0	0	0	.80	.16	.48	.32	0	.16	.16	.16	.32	0	0	.16	.16	0	0	0	0	0
21	0	0	0	0	.32	.32	0	0	.16	.16	0	.16	.16	0	.32	.32	0	0	0	0	0	0
22	0	0	0	0	0	.16	1.12	.16	0	.16	.16	.32	.16	.16	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	.16	1.12	1.12	.64	1.12	.80	.64	.32	.16	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	.16	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-48. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK B 20MPH
TEST 64

VAC \ RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	.96	1.12	.48	0	.32	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	.48	0	.16	.48	1.29	.48	.64	.48	0	0	0	0	0	0
3	0	0	0	0	.16	0	.16	0	.32	0	.16	.32	0	.16	0	.80	.16	0	0	0	0	0
4	0	0	0	.16	.16	.16	.16	.32	0	.32	.32	0	0	.32	.16	0	.16	0	0	0	0	0
5	0	0	.16	.32	0	0	.16	0	.16	.32	.32	.48	.16	.16	.16	0	0	0	0	0	0	0
6	0	0	0	0	0	0	.16	0	.16	0	.32	.32	0	0	0	0	.48	0	0	0	0	0
7	0	0	0	0	0	0	.16	.16	.16	.32	.64	.48	0	0	0	0	1.12	0	0	0	0	0
8	0	0	0	0	0	.16	0	.16	0	0	.16	.32	.16	.48	0	0	1.77	0	0	0	0	0
9	0	0	0	0	.16	.16	0	0	0	.16	.16	.16	0	.48	2.74	0	.16	0	0	0	0	0
10	0	0	0	.16	.16	0	0	.32	.16	0	.32	0	.16	1.27	.48	0	0	0	0	0	0	0
11	0	0	.16	0	.16	.32	0	.32	.32	0	0	0	0	2.25	.16	0	0	0	0	0	0	0
12	0	0	0	0	.16	.16	.32	0	.48	.16	.16	1.12	0	.16	0	.16	0	0	0	0	0	0
13	0	0	0	0	.16	.16	0	.16	.32	.32	1.45	.80	.16	.16	.16	0	0	0	0	0	0	0
14	0	0	6.45	0	.16	0	0	.32	.32	.48	.96	.64	.16	0	.32	0	0	0	0	0	0	0
15	0	0	10.32	.16	.48	0	0	1.12	.32	.16	.48	.32	0	0	0	.16	0	0	0	0	0	0
16	0	0	.96	0	0	.32	0	0	.48	.48	.32	0	0	0	.48	0	0	0	0	0	0	0
17	0	0	0	.16	.16	.48	0	.32	.16	.16	.16	0	.48	0	0	0	0	0	0	0	0	0
18	0	0	0	.32	.48	.48	0	.32	0	.16	0	.32	.32	0	.16	.48	0	0	0	0	0	0
19	0	0	0	.32	.80	.32	0	.32	0	.32	0	0	.16	0	.48	.64	0	0	0	0	0	0
20	0	0	0	.16	.96	.48	0	.16	.64	.32	0	0	.16	0	.32	0	0	0	0	0	0	0
21	0	0	0	0	.96	0	0	.96	0	0	0	.32	.16	.32	0	0	0	0	0	0	0	0
22	0	0	0	0	.16	1.12	.16	.16	.32	0	0	.16	0	.16	.16	0	0	0	0	0	0	0
23	0	0	0	0	0	.16	1.93	1.61	.16	0	.32	.16	.16	.16	.16	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	.64	.64	.32	1.12	.48	.48	.32	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-49. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 9 20MPH TEST 64	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	.13	.13	.13	.13	.27	.13	0	2.89	4.60	2.79	3.87	5.16	5.50	0	0	0	0	0	0
	1	0	0	0	.41	.13	.13	0	0	0	0	0	.13	.13	.27	.27	.41	.41	0	.13	0	0	0
	2	0	0	0	0	0	0	.13	0	0	0	.13	.41	.13	0	0	0	0	.13	0	0	0	0
	3	0	0	0	0	0	.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	.13	.13	.13	0	.27	.13	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	.13	.13	.13	.13	0	.13	.13	1.11	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	.13	0	0	0	.13	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	.13	0	0	0	0	.13	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	.13	0	.13	.13	0	0	0	.13	0	0	0	0	0	0	0
	9	0	0	0	0	0	.13	0	.13	0	0	.13	.27	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	.13	0	.13	.13	0	.27	.13	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	.13	.13	0	0	0	.13	.13	0	.13	0	0	0	0	0	0	0
	12	0	0	0	0	0	0	.13	0	0	.13	.13	0	.13	.13	.13	0	0	0	0	0	0	0
	13	0	0	0	0	.13	.13	0	0	.13	.13	.27	.13	.27	.13	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	.13	0	0	0	.13	0	.27	0	0	0	.13	0	0	0	0	0	0
	15	0	0	0	0	0	.13	.13	0	.13	0	0	.41	.13	0	.69	.13	0	0	.13	0	0	0
	16	0	0	0	0	.13	0	0	0	0	.13	0	.13	.27	.27	0	0	0	0	0	0	0	0
	17	0	0	0	0	.27	.13	0	0	1.11	0	0	.55	.13	0	.83	0	0	0	0	0	0	0
	18	0	0	0	.13	.41	.41	0	0	.83	.69	0	.69	0	.13	.97	0	0	0	0	0	0	0
	19	0	0	0	19.83	12.98	.69	0	0	.27	.69	0	1.53	0	0	.27	0	0	0	0	0	0	0
	20	0	0	0	0	1.67	.41	0	0	.97	.69	0	.41	0	0	.13	.13	.13	0	0	0	0	0
	21	0	0	0	0	0	.97	.41	.13	1.11	.83	.13	.27	0	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	.13	.55	.13	.13	.41	0	.13	.13	0	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	.13	.55	.97	.13	.41	.41	0	.41	.13	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0	.55	.83	.13	.27	.13	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-50. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 10 20MPH
TEST 66

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	.55	0	0	0	0	0	0	0	1.10	1.51	1.65	2.89	0	0	0	0	0	0	0	0	0	0
1	1.23	.13	0	0	0	0	0	0	.27	.82	3.16	10.33	2.61	.55	.13	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	.27	0	.55	.41	.27	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	.13	.13	.13	.13	.41	0	.13	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	.13	.55	.27	.41	.13	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	.13	0	.13	.13	.13	.13	0	0	0	0	0	0	0	0	0
6	.27	0	.13	0	0	.13	0	.13	.27	.13	.13	.55	.13	0	0	0	0	0	0	0	0	0
7	0	0	0	.13	.13	.13	0	.13	.13	0	.27	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	.13	0	0	.27	.13	0	.13	0	0	0	0	0	0	0	0	0	0
9	0	0	0	.27	0	0	0	0	.13	.13	.68	.27	.13	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	.41	.55	0	.27	.13	0	0	0	0	0	0	0	0	0	0
11	0	.13	0	0	0	0	0	.55	.55	.13	.68	.27	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	.13	.13	.27	0	.55	.13	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	.13	0	0	.13	.13	0	.55	.13	0	0	0	0	0	0	0	0	0	0
14	0	0	.13	0	0	.13	.13	.41	.68	.41	.68	0	0	0	0	0	0	0	0	0	0	0
15	0	0	.13	.13	.13	0	.55	.13	.55	.55	.41	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	.13	.27	.27	0	1.10	.13	.41	.13	0	0	0	0	0	0	0	0	0	0
17	0	.13	.13	.13	0	.13	.96	0	.27	.13	0	.41	0	0	0	0	0	0	0	0	0	0
18	0	0	.13	.13	0	.55	.55	.13	.96	.68	0	.13	0	0	0	0	0	0	0	0	0	0
19	0	0	3.84	19.50	0	.55	.96	.13	.27	0	.27	.27	0	0	0	0	0	0	0	0	0	0
20	0	0	3.03	7.30	.13	.55	.41	.13	0	0	.13	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	.27	.27	1.10	0	0	.13	.13	.13	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	.13	.27	.27	.13	0	.27	.13	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	.13	.27	.68	.41	.68	.41	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	.13	.27	.41	.13	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-51. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 11 20MPH TEST 64	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	.96	1.38	.13	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	.27	.27	.69	3.73	1.10	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	.13	.27	.41	.83	5.54	2.90	4.70	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	.13	0	.13	.13	.13	.55	.27	.27	.69	2.63	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	.13	0	0	0	.96	.41	.13	0	.13	0	0	0	0
	7	0	0	0	0	.13	.13	0	0	0	0	0	.13	.13	0	0	.13	0	0	0	0	0	0
	8	0	0	0	0	0	.13	0	0	0	.13	0	.13	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	.13	0	.41	.13	.13	0	.13	0	0	0	0	0
	10	0	0	0	0	0	.13	.13	0	0	.13	.13	.27	.13	.27	.41	0	0	.13	0	0	0	0
	11	0	0	0	0	0	.13	0	0	.13	.13	0	.13	0	0	0	.13	0	0	0	0	0	0
	12	0	0	0	0	0	.13	.27	.13	0	0	.13	.13	0	0	.13	0	.13	0	0	0	0	0
	13	0	0	.13	.13	0	.13	0	.13	0	0	0	.13	0	0	.13	.13	0	0	0	0	0	0
	14	0	0	0	0	0	0	.27	.13	.69	.13	0	.55	0	0	.27	0	0	0	0	0	0	0
	15	0	0	0	.41	.13	0	.13	.13	.41	0	.13	.41	.27	0	.55	0	0	0	0	0	0	0
	16	0	0	.27	2.21	0	0	0	.13	.13	0	.13	.13	.13	.13	.69	0	0	0	0	0	0	0
	17	0	0	.13	31.85	0	.13	0	.13	.41	.13	.13	.41	0	0	.27	.13	0	0	0	0	0	0
	18	0	0	0	1.57	0	0	.83	.41	.83	0	.55	.13	0	.41	.27	0	0	0	0	0	0	0
	19	0	0	0	.13	.27	0	.27	.41	.27	0	.27	.13	.41	.13	1.10	0	0	0	0	0	0	0
	20	0	0	0	0	.13	.69	0	0	.13	.13	.13	.96	0	.27	.41	0	0	0	0	0	0	0
	21	0	0	0	0	0	.41	.13	0	0	0	.41	.41	.13	.55	.27	0	.13	0	0	0	0	0
	22	0	0	0	0	0	.13	.55	.13	.27	.13	0	.13	.13	.13	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	.27	.13	.83	.69	.55	.55	.41	.27	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0	.13	.27	.55	.27	.13	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-53. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 12 20MPH
TEST 64

VAC \ RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	1.48	1.21	6.35	4.05	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	.67	.80	.40	.81	3.64	7.02	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	.27	.54	.27	0	.27	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	.13	.40	.13	0	.13	0	0	0	0	0	0	0
5	0	0	0	0	0	0	.13	0	.13	0	.13	0	.13	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	.13	0	.27	.13	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	.13	0	.13	.13	0	.13	0	0	0	0	0	0	0	0
8	0	0	0	0	.13	0	.13	.27	.27	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	.13	.13	.40	0	.13	.27	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	.13	.13	.40	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	.13	.13	0	0	0	.40	.27	.67	.13	0	0	0	0	0	0	0	0	0
12	0	0	0	0	.27	.13	0	.13	0	.13	0	0	.13	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	.13	0	.13	.13	.13	.13	0	.13	0	.13	0	0	0	0	0	0	0
14	0	0	0	0	.13	0	.27	0	.27	.13	.40	.13	0	.13	0	0	0	0	0	0	0	0
15	0	0	0	0	0	.13	0	.27	.40	.67	.40	.54	.81	0	0	0	0	0	0	0	0	0
16	0	0	0	.13	0	0	.13	.27	0	.40	.54	0	.13	0	0	0	0	0	0	0	0	0
17	0	0	0	.13	.13	0	.27	0	.27	.27	.40	.27	.13	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	.27	.13	.13	.13	.54	.54	.13	.13	0	0	0	0	0	0	0	0	0
19	0	0	17.14	0	0	0	.27	.40	.13	.54	.13	.94	0	0	0	0	0	0	0	0	0	0
20	0	0	10.94	.54	.27	1.08	.81	.27	0	.54	.13	.13	0	0	0	0	0	0	0	0	0	0
21	0	0	0	.54	0	.54	.27	.13	0	.40	0	.40	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	.81	.27	.40	0	0	.27	.13	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	.54	.67	.67	.13	.13	.13	.54	.13	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	.67	1.08	.94	.67	.94	.27	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-53. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 13 20MPH TEST 04	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	.13	0	0	0	0	.81	3.10	7.16	2.63	2.02	.27	0	0
	2	.13	0	0	0	0	0	0	0	0	0	0	0	.40	.54	.27	.81	.54	.13	.40	.13	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	.27	.40	.54	.27	.40	.13	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.13	0	0	.13	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	.27	0	.13	0	0	.27	.13	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	.27	0	0	.40	0	0	.40	0	0	0	0
	7	.13	0	0	0	0	.13	0	0	.13	0	0	.13	.40	0	.81	0	.40	0	0	0	0	0
	8	.13	0	0	0	0	0	0	0	0	0	0	.27	.27	.27	.27	0	0	.13	0	0	0	0
	9	0	0	0	0	0	0	0	.13	0	0	.13	0	0	.13	.40	0	.13	.13	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	.94	0	.13	0	.27	.13	.27	.13	0	0	0
	11	.13	0	0	0	0	0	0	0	0	.13	0	.27	0	0	.13	0	0	.27	0	0	0	0
	12	0	0	0	0	0	.27	0	0	.13	.13	.13	.13	.13	.13	0	0	.13	.27	.13	0	0	0
	13	0	0	0	0	0	0	0	.27	0	.13	.13	.40	.27	.54	.27	0	0	0	.27	0	0	0
	14	0	0	0	0	0	0	.13	.13	.13	0	.27	.40	0	0	.13	0	.27	0	.13	0	0	0
	15	0	0	.13	.13	0	0	.13	0	.13	.13	.13	.13	0	.54	.67	0	.67	0	.13	0	0	0
	16	0	0	0	.27	0	0	0	.13	0	.13	.27	.13	.13	1.08	.40	.13	.81	0	0	0	0	0
	17	0	0	0	10.24	0	0	.40	.13	0	0	.54	.40	0	1.75	.81	.13	0	0	0	0	0	0
	18	0	0	0	17.14	0	0	.27	.27	0	0	.67	0	.27	1.08	.81	0	0	0	0	0	0	0
	19	0	0	0	.13	.13	0	.67	.27	0	.13	.27	0	.54	.40	.27	.27	0	0	0	0	0	0
	20	0	0	0	0	.40	0	.27	0	0	0	.13	0	0	.13	0	.27	0	.13	0	0	0	0
	21	0	0	0	0	0	.40	.13	0	0	.13	0	.13	.13	0	.13	.13	0	0	0	0	0	0
	22	0	0	0	0	0	0	.40	.40	0	0	.13	0	.13	.13	.27	0	.13	.13	0	0	0	0
	23	0	0	0	0	0	0	0	.13	.40	.54	1.21	.13	.40	.27	.13	.27	0	.13	0	0	0	0
	24	0	0	0	0	0	0	0	0	0	0	.13	.81	.94	.67	.67	.13	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-54. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 14 20MPH
TEST 64

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	.27	7.16	6.72	2.56	1.75	1.62	.40	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	.13	0	.67	0	.27	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	.27	.27	.13	.27	.13	.13	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	.13	.13	.40	0	0	0	.13	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	.81	0	.13	.13	.13	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	.27	0	.27	.13	.13	0	0	0	0	0	0
7	0	0	0	0	0	0	0	.13	0	0	0	.40	.13	.27	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	.13	.13	.13	.40	.13	.13	.13	0	0	0	0	0	0	0
9	0	0	0	0	0	.27	0	0	0	0	0	0	.13	.13	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	.13	.13	.13	.13	0	.13	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	.13	.54	.27	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	.13	0	0	0	0	.40	.94	.54	.27	0	.13	.13	0	0	0	0	0
13	0	0	0	0	0	0	0	.13	0	.13	.40	.13	.27	.13	1.08	.13	.13	0	0	0	0	0
14	0	0	0	0	0	0	0	.13	0	.13	.27	.13	.40	.40	.13	.27	.13	0	0	0	0	0
15	0	0	0	.13	0	.13	.13	.13	0	.13	0	.13	.81	0	.27	0	0	0	0	0	0	0
16	0	0	0	.13	0	0	0	0	0	.13	.54	.13	1.48	0	.13	.13	0	0	0	0	0	0
17	0	0	0	.13	0	0	0	0	.13	.27	.54	.40	.27	.81	.27	0	0	0	0	0	0	0
18	0	0	0	19.59	0	0	0	.40	0	.13	0	.13	.54	.13	0	0	0	0	0	0	0	0
19	0	0	0	16.89	0	0	.54	.27	0	.40	.13	.54	.27	.13	0	0	0	0	0	0	0	0
20	0	0	0	0	.54	0	.40	.27	.13	.40	0	.27	.27	.13	.13	0	0	0	0	0	0	0
21	0	0	0	0	.13	.40	.13	.13	0	.13	.13	0	.27	.13	.40	0	0	0	0	0	0	0
22	0	0	0	0	0	.27	.40	.13	0	0	0	0	.13	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	.40	.67	.40	0	.27	0	.27	.27	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	.67	1.21	.94	.40	.40	.27	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	.27	.54	.40	.27	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-55 PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 15 20MPH
TEST 64

VAC \ RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	.41	2.36	2.01	2.36	1.38	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	.13	.13	.13	.69	.27	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.13	.55	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.13	1.38	.27	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	.13	0	2.36	.13	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.13	2.63	0	.27	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.27	1.25	.27	.13	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	.13	.27	.41	.41	.83	.13	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	.69	.27	.55	.55	.41	0	0	0	0	0
11	0	0	0	0	0	0	0	0	.13	0	0	0	.41	.13	.69	.13	.27	.13	0	0	0	0
12	0	0	0	0	0	0	0	.13	0	0	0	0	0	.13	0	.83	.41	.41	0	0	0	0
13	0	0	0	0	0	.13	.27	0	0	0	0	.13	.13	0	.27	.13	.13	.27	0	0	0	0
14	0	0	0	0	.13	0	0	.13	0	0	.13	.13	0	.41	.27	.55	.13	.13	0	0	0	0
15	0	0	0	.13	.13	0	.13	.13	0	0	.13	0	.41	.13	.13	.13	.13	0	0	0	0	0
16	0	0	0	0	0	0	0	0	.13	.13	0	.13	.27	.27	.13	.13	.55	0	0	0	0	0
17	0	0	0	0	0	0	.13	0	0	.13	0	.13	.83	.41	0	0	1.21	.41	0	0	0	0
18	0	0	0	7.77	0	0	0	0	0	.27	.13	.13	1.52	.55	.27	.55	1.38	.27	0	0	0	0
19	0	0	0	27.63	0	.13	0	.13	.13	.13	0	.13	.83	.69	.13	.55	0	0	0	0	0	0
20	0	0	0	.13	0	0	0	0	0	.13	1.38	.27	.83	1.52	.13	.97	.27	0	0	0	0	0
21	0	0	0	0	.13	.27	0	0	0	0	.41	0	.27	.27	.13	.27	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	.27	.27	.27	.13	0	.13	0	0	0	0	0
23	0	0	0	0	0	0	.13	.55	0	0	.13	.13	.13	0	0	.27	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	.41	.41	.97	.55	.27	.55	.69	.27	.13	.13	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	.27	.69	.83	.41	.41	.27	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-56. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 16 20MPH TEST 66	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	.82	.96	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	.13	.68	2.61	2.61	1.92	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	.13	.13	.13	.41	.82	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	.13	.27	.13	.55	.13	0	0	0	0	0
	5	0	0	0	0	0	0	.13	0	.13	0	0	0	0	.41	.13	.41	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	.13	.13	0	.27	1.65	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	.13	.13	.41	.13	6.86	.13	0	0	0	0	0
	8	0	0	0	.13	0	0	0	.13	0	0	.13	.13	.55	.13	.41	.41	0	0	0	0	0	0
	9	0	0	0	0	0	.13	0	0	0	0	0	0	.13	0	.13	.27	0	0	0	0	0	0
	10	0	0	0	0	.27	0	0	.13	0	.13	0	.41	.27	.27	.41	.27	0	0	0	0	0	0
	11	0	0	0	0	0	.13	0	.27	0	.13	.13	0	.68	.13	.27	.27	.13	0	0	0	0	0
	12	0	0	0	0	.13	0	0	0	.27	0	.27	.82	.41	0	.55	0	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	0	0	.13	.27	.27	0	.41	.27	0	0	0	0	0	0
	14	0	0	0	0	0	.13	0	.13	0	0	0	.27	.27	0	.55	.13	0	0	0	0	0	0
	15	0	0	0	.13	0	.27	.27	.13	0	.41	.13	.41	.13	0	.41	.13	0	0	0	0	0	0
	16	0	0	0	4.54	0	0	0	0	0	.13	.13	.68	.82	.13	1.79	.55	0	0	0	0	0	0
	17	0	0	0	28.65	2.61	0	.13	0	0	0	.13	.55	.41	.68	1.23	.27	0	0	0	0	0	0
	18	0	0	0	0	.41	.13	.13	0	0	0	.27	.27	2.20	2.34	.55	.13	0	0	0	0	0	0
	19	0	0	0	0	.13	.27	1.37	.13	0	.13	.13	.13	.55	.41	.13	0	0	0	0	0	0	0
	20	0	0	0	0	0	.13	.27	.13	0	.13	0	.13	0	.55	.41	0	0	0	0	0	0	0
	21	0	0	0	0	0	0	.13	.41	.13	.27	0	0	.41	.55	.27	.13	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	.27	.41	.27	.82	.68	.27	.41	.27	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	0	0	0	0	.27	.27	.27	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-57. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 17 20MPH
TEST 64

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	.48	.80	.96	.32	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	.16	0	.16	.96	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	.32	.32	.16	0	.80	.16	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	.16	.48	.32	.16	.32	.16	.16	.16	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	.16	.16	.16	.16	2.89	0	0	.16	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	.16	0	.64	.64	1.44	.16	.32	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	.16	0	.64	2.25	.80	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	.16	0	1.12	1.60	.16	0	.16	0	0	0	0	0	0
9	0	0	0	0	.16	0	0	0	.64	.48	.16	1.44	.48	.16	0	.32	0	0	0	0	0	0
10	0	0	0	0	.16	0	0	0	.16	.80	.80	.16	.32	.32	.48	0	0	0	0	0	0	0
11	0	0	0	.16	.16	0	.16	0	.16	0	.48	.16	.64	.32	0	.16	0	0	0	0	0	0
12	0	0	0	.16	.16	0	.16	0	.16	.32	.32	.16	.64	1.12	.16	.16	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	.16	0	.48	.16	2.73	.16	.32	0	.16	0	0	0	0	0
14	0	0	0	0	0	.16	.16	0	.32	0	.80	.16	.64	.16	0	0	0	0	0	0	0	0
15	0	0	.16	.16	.32	.16	0	0	.16	.16	.96	.32	.32	.16	.48	.16	0	0	0	0	0	0
16	0	0	0	0	0	.32	0	0	.32	0	.32	.64	.32	0	.64	.16	.32	0	0	0	0	0
17	0	0	2.57	.16	0	0	0	.16	.64	.16	.48	.96	.32	0	.16	0	0	0	0	0	0	0
18	0	0	5.14	0	0	0	.32	0	.96	0	.16	.80	.16	.16	0	0	.16	0	0	0	0	0
19	0	0	7.07	0	0	.48	0	.16	1.12	0	0	.80	.16	0	.16	.16	0	0	0	0	0	0
20	0	0	9.64	.32	.16	1.28	.16	.16	.32	0	0	1.76	.16	0	0	0	0	0	0	0	0	0
21	0	0	0	.32	0	.80	.64	0	.32	0	.16	0	0	.16	0	.16	0	0	0	0	0	0
22	0	0	0	.16	0	0	0	0	.96	0	.32	.16	0	0	0	.16	0	0	0	0	0	0
23	0	0	0	.16	.32	0	0	0	.32	0	0	0	.32	.32	.16	0	0	0	0	0	0	0
24	0	0	0	0	.32	.48	.32	.16	.32	0	.16	0	.16	0	.16	0	0	0	0	0	0	0
25	0	0	0	0	0	.16	1.28	1.60	.80	.64	.80	.32	.32	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	.16	.16	.32	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE D-59. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 17 20MPH
TEST 64

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	1.19	2.38	.85	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	.17	.34	.17	1.36	.17	.34	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	.34	.51	0	.17	0	.51	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	.17	.34	.34	.17	.51	.17	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	.17	.34	.34	.51	1.87	.51	.17	0	0	0	0	0	0
6	0	0	0	0	0	0	.17	0	0	0	0	.34	.34	.51	.17	.17	.17	0	0	0	0	0
7	0	0	0	0	0	0	0	0	.17	0	0	.34	.51	.17	.17	.17	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	.34	1.19	.51	.51	.17	.17	0	0	0	0	0	0
9	0	0	0	.17	0	0	0	0	.17	.17	.17	1.02	.17	.34	.34	.17	.17	0	0	0	0	0
10	0	0	0	0	0	0	0	.17	0	.34	1.70	0	.51	.51	0	0	.17	.17	0	0	0	0
11	0	0	0	0	.68	.17	.17	0	0	.17	.68	.17	.68	1.02	1.02	.17	.17	0	0	0	0	0
12	0	.17	0	0	0	0	0	.17	0	0	.68	.34	.34	1.02	.51	.51	0	.34	0	0	0	0
13	0	0	0	0	0	0	.17	0	.17	0	.51	.17	1.19	.17	.17	.17	0	0	0	0	0	0
14	0	0	.17	.17	.17	.17	0	0	0	.34	.51	.17	.34	0	.34	0	.17	.34	0	0	0	0
15	0	0	.17	.17	.17	.17	0	0	.17	.17	1.53	.17	.34	0	.85	0	0	.51	0	0	0	0
16	0	0	.17	0	0	0	0	0	0	.17	.51	.34	.17	0	1.36	0	0	.17	0	0	0	0
17	0	0	.34	.17	0	.17	0	0	.17	.51	.51	.68	.17	0	.17	0	0	0	0	0	0	0
18	0	0	5.44	.17	0	.17	.17	0	.17	0	0	1.02	0	.17	0	.17	0	0	0	0	0	0
19	0	0	13.99	.17	0	0	0	0	.68	.34	.51	1.87	0	0	0	0	.17	0	0	0	0	0
20	0	0	2.55	4.09	0	0	.34	0	.34	0	0	.17	0	0	0	0	.17	0	0	0	0	0
21	0	0	0	.51	0	0	.34	0	0	.17	0	.85	.17	.17	.34	0	0	0	0	0	0	0
22	0	0	0	0	.34	0	0	0	0	.17	.17	.17	0	0	0	.17	0	0	0	0	0	0
23	0	0	0	0	.51	0	.17	0	0	0	.17	.17	0	.17	0	0	.17	0	0	0	0	0
24	0	0	0	0	.17	.85	.51	0	.34	0	0	.17	.17	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	.85	1.53	1.19	1.36	1.02	.85	.68	.17	0	.17	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-59. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 17 20MPH
TEST 64

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	.32	.80	.80	.96	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	.16	0	.16	.48	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	.16	0	0	.48	.16	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	.16	.32	.16	.32	.48	.16	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	.48	.64	.48	1.60	.16	.16	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	.16	.16	.64	.32	2.08	.16	0	.32	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	.16	.64	1.12	0	0	.32	0	0	0	0	0	0	0
8	0	0	0	0	0	0	.16	0	.16	.16	1.44	2.24	.80	0	.16	0	0	0	0	0	0	0
9	0	0	0	.16	0	0	0	.32	0	.48	1.12	.80	0	.48	.16	0	0	0	0	0	0	0
10	0	0	0	.16	.16	0	0	.16	0	.48	.80	.48	0	.32	.16	0	0	0	0	0	0	0
11	0	0	0	.16	0	0	0	0	0	.48	.16	.16	.16	.48	0	.16	0	0	0	0	0	0
12	0	0	0	.16	0	0	0	0	.32	.48	.16	.48	0	.80	.16	0	0	0	0	0	0	0
13	0	0	0	0	0	.16	.16	.16	0	.48	.32	3.04	.32	.16	0	0	0	0	0	0	0	0
14	0	0	0	.32	.16	0	0	0	.32	.64	.32	.80	.32	0	.16	0	0	0	0	0	0	0
15	0	0	0	0	.16	.16	0	.16	.32	1.12	.48	.16	.32	.16	0	.16	0	0	0	0	0	0
16	0	0	0	.16	0	0	.16	0	1.44	.64	.48	.32	0	.64	0	.16	0	0	0	0	0	0
17	0	0	.16	0	0	.32	0	.32	.16	.32	.64	.64	0	.16	0	0	0	0	0	0	0	0
18	0	0	5.44	0	0	0	.16	.32	.16	.16	.32	.48	.16	.16	.16	.32	0	0	0	0	0	0
19	0	0	9.77	0	.16	.32	0	.32	.64	0	.80	.16	.16	.16	0	.16	0	0	0	0	0	0
20	0	0	9.03	.16	0	1.92	0	.16	.32	.16	1.12	.32	.32	.32	0	0	0	0	0	0	0	0
21	0	0	0	.48	0	.96	0	.16	.64	0	.16	0	0	0	.16	.16	0	0	0	0	0	0
22	0	0	0	.32	.32	.16	0	.80	.16	.16	0	.32	.16	0	0	0	0	0	0	0	0	0
23	0	0	0	.32	.16	.16	0	0	0	0	0	.16	.16	0	0	0	0	0	0	0	0	0
24	0	0	0	0	.80	.16	.16	.32	.48	.32	0	0	.16	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	.64	1.60	1.28	.64	.48	.32	.48	.16	.16	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	.16	.16	.32	.16	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 9-60. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 18 20MPH
TEST 64

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	.13	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	.13	0	0	0	0	0	0	.13	.13	1.08	5.54	6.62	8.37	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	.27	.27	.27	.27	.94	.27	0	0	0	0
4	0	0	0	0	0	0	0	0	0	.13	0	.13	.13	.67	0	.40	0	.40	0	0	0	0
5	0	0	0	0	0	.13	0	0	0	0	0	0	.13	.27	.13	.13	.13	.13	0	0	0	0
6	0	0	0	0	0	0	0	0	0	.13	0	.13	0	0	0	0	0	.13	0	0	0	0
7	0	0	0	.13	0	0	.13	0	.13	.13	.13	.13	.13	.27	.27	.27	.13	.13	0	0	0	0
8	0	0	0	.13	0	0	0	0	0	.13	0	.13	0	.27	.67	.27	0	.13	0	0	0	0
9	0	0	0	0	0	0	0	0	0	.13	0	.54	.27	.13	.40	0	0	0	0	0	0	0
10	0	0	0	0	.13	0	0	0	0	0	0	0	.13	.40	.27	.13	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	.13	.13	.27	.13	.13	0	0	0	0	0
12	0	0	0	.13	0	0	0	.13	0	0	.13	.13	.67	.27	.40	.40	0	0	0	0	0	0
13	0	0	0	0	0	0	.13	.13	.13	0	.27	.27	.27	.40	.40	.54	0	0	0	0	0	0
14	0	0	0	0	0	.13	0	0	0	0	.40	0	.40	.81	.67	.13	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	.13	.40	0	.67	1.08	.81	0	.13	0	0	0	0	0
16	0	0	0	.13	.13	.13	0	0	0	.13	.54	.13	0	.40	.13	0	.13	0	0	0	0	0
17	0	0	0	0	0	.13	.27	0	0	.13	0	0	.27	.27	0	.27	0	0	0	0	0	0
18	0	0	0	.40	.13	.13	.13	0	0	.27	.13	.13	.54	.13	.40	0	0	0	0	0	0	0
19	0	0	0	20.91	0	0	.94	.13	.13	0	0	0	.94	.27	.13	.13	0	0	0	0	0	0
20	0	0	0	5.81	0	0	.54	0	0	0	0	0	.13	0	.27	0	0	0	0	0	0	0
21	0	0	0	.13	.13	.27	.27	0	0	0	0	0	.27	0	0	0	0	0	0	0	0	0
22	0	0	0	0	.40	.27	0	0	0	0	.13	0	.40	.13	0	0	0	0	0	0	0	0
23	0	0	0	0	0	.13	.27	0	0	0	0	.13	.13	0	0	.13	0	0	0	0	0	0
24	0	0	0	0	0	0	.13	.81	.67	.67	.13	0	.27	.13	.13	.13	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	.67	1.08	.94	1.08	.13	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-61. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 18 20MPH
TEST 64

RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	1.50	7.94	6.16	5.47	0	0	0	0	0	0
3	0	0	0	0	0	.13	0	0	0	0	0	.13	.68	.68	.13	.95	.13	0	0	0	0	0
4	0	0	0	0	.13	0	0	0	0	0	0	.27	0	.13	.13	0	0	0	0	0	0	0
5	0	0	0	.13	0	.13	0	0	0	0	.13	.27	.27	.54	0	.27	0	0	0	0	0	0
6	0	0	0	0	0	.13	0	0	.13	0	0	0	.13	.13	0	0	0	0	0	0	0	0
7	0	0	0	.13	.13	0	0	0	0	0	0	0	0	.27	.13	.0	.13	0	0	0	0	0
8	0	0	0	0	0	.13	0	0	.13	0	.13	0	.27	.41	0	.13	0	0	0	0	0	0
9	0	0	0	0	0	0	0	.13	.27	0	0	0	.41	.68	.13	0	.13	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	.41	.54	.27	.13	.27	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	.13	0	.13	0	.13	.13	.27	.13	.13	0	.13	0	0	0	0	0
12	0	0	0	0	.13	0	0	0	0	.27	.27	.41	.13	0	0	0	0	0	0	0	0	0
13	0	0	0	.13	0	0	0	0	0	.13	.41	.54	0	.27	0	0	0	0	0	0	0	0
14	0	0	0	.13	0	0	.13	0	.13	.13	.27	.27	.54	.68	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	.13	.82	.95	0	.27	.13	0	0	0	0	0	0	0
16	0	0	0	0	.13	0	.13	0	.13	.68	.95	.41	0	.41	0	0	0	0	0	0	0	0
17	0	0	0	.13	0	.13	0	0	.13	.41	.27	.54	.13	.27	0	0	0	0	0	0	0	0
18	0	0	.27	0	0	.13	0	0	0	.54	1.09	.54	0	0	0	0	0	0	0	0	0	0
19	0	0	26.30	10.12	0	.13	.68	0	0	.27	.27	.13	.13	.27	0	0	0	0	0	0	0	0
20	0	0	.41	.27	.82	0	.41	0	0	0	.13	.68	0	.13	0	0	0	0	0	0	0	0
21	0	0	0	.27	.13	.27	.27	0	0	.27	0	.27	.27	0	0	0	0	0	0	0	0	0
22	0	0	0	.13	.27	.13	0	0	0	0	.27	.41	.41	0	0	0	0	0	0	0	0	0
23	0	0	0	0	.41	.27	0	0	.13	.13	0	.13	.13	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	.27	.41	.54	.41	.13	.27	.41	.54	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	.27	.13	.68	.68	.68	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 9-42. PERCENT TIME IN RPM-VACUUM INTERVALS FOR 32 kph CYCLE

TRUCK 18 20MPH TEST 64	RPM VAC	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	.13	0	0	0	.67	2.83	1.29	6.21	5.27	0	0	0	0
	3	0	0	0	0	0	.13	.13	0	0	0	0	0	0	.27	.13	.40	.27	.40	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	.27	0	.13	.13	0	.40	.27	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	.13	.13	.13	0	.27	.13	.13	0	0	0	0	0
	6	0	0	0	0	0	.13	0	0	0	0	.13	0	0	.27	.27	.40	.13	.13	.13	0	0	0
	7	0	0	0	0	0	0	.40	0	0	0	.27	0	.13	.13	.40	0	0	.13	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	.27	.13	.27	.13	.27	0	.40	0	0	0	0	0
	9	0	0	0	0	0	.13	0	0	0	.13	0	0	0	.13	.40	.27	.13	.13	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	.40	.13	.27	.40	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	.13	0	.13	0	.27	.13	0	.27	.27	.27	.13	0	.13	0	0	0
	12	0	0	0	0	0	0	0	.13	0	0	0	.40	0	.94	.13	.27	0	.27	0	0	0	0
	13	0	0	0	0	.13	0	.13	0	0	.13	0	0	.13	.81	.94	0	1.08	0	0	0	0	0
	14	0	0	0	0	0	0	0	0	0	0	0	.40	0	1.08	.40	.81	.13	0	0	0	0	0
	15	0	0	0	0	0	.13	.13	0	0	0	.40	0	.13	.54	.94	.13	0	.13	0	0	0	0
	16	0	0	0	0	.13	0	.13	0	.13	0	.40	0	.13	1.75	.13	.13	0	0	0	0	0	0
	17	0	0	0	.13	0	0	0	.13	0	0	0	0	0	.54	0	0	.13	0	0	0	0	0
	18	0	0	0	.40	0	0	.27	0	0	0	0	.13	0	.54	.13	.13	0	0	0	0	0	0
	19	0	0	0	35.13	0	0	1.08	0	0	.13	.13	0	.13	.13	.13	0	0	0	0	0	0	0
	20	0	0	0	0	.27	0	.81	0	0	.13	0	0	.13	.54	.27	.13	0	0	0	0	0	0
	21	0	0	0	0	.54	0	0	0	0	0	.13	0	.27	.13	0	.27	0	0	0	0	0	0
	22	0	0	0	0	0	.81	0	0	0	0	0	0	0	.40	0	.13	0	0	0	0	0	0
	23	0	0	0	0	0	0	.27	.40	0	.13	0	0	.27	.13	0	.13	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	.67	.54	1.08	.94	.54	.40	.27	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0	.13	.40	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE B-63. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, DRIVING CYCLE HC

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	1.3779	1.70936	0.0173	0.3066	0.2700	0.6242	0.0573	0.1120	0.6015	0.6991	24.03
2	1.7224	2.4627	0.0777	0.3315	-0.2293	0.8992	0.1017	0.1210	0.6566	0.6722	18.98
3	1.5121	2.5149	0.0549**	0.3401	0.0624**	0.9183	0.0746**	0.1242	0.6342	0.7214	21.11
4	5.1663	0.6220	-0.3448	0.0845	-0.6069	0.2271	0.1283	0.0300	0.8844	0.1859	5.35
5	3.2989	1.9126	-0.0384	0.2613	-1.2974	0.6984	0.0688	0.0954	0.3126	0.6029	17.18
6	7.8311	3.8917	-0.0199	0.5293	-1.1675	1.4211	0.1329	0.1933	0.2762	1.1788	16.48
7	2.8448	2.6412	-0.1294	0.3587	-0.5379	0.9644	0.1630	0.1310	0.6500	0.7894	22.55
8	9.2844	7.8590	0.0349	1.0690	-1.4693	2.8697	0.3014	0.3903	0.3912	2.3806	21.12
9	3.8143	4.1740	-0.1330	0.3095	-2.0493	1.5241	0.2992*	0.1130	0.8411	1.9869	30.56
10	0.2504	2.0400	0.2506	0.1513	2.0908*	0.7449	-0.0149	0.0552	0.8968	0.9711	11.86
11	1.1159	0.6059	0.0998	0.0460	0.4948	0.2213	0.0108	0.0168	0.9214	0.3501	9.03
12	3.4272	1.7024	0.0305	0.1262	1.7784*	0.6216	-0.0045	0.0461	0.8945	0.8104	9.98
13	0.4113	1.1604	0.1128	0.0860	1.1594*	0.4237	0.0125	0.0314	0.9276	0.5524	10.75
14	5.4822	2.2890	-0.0378	0.1697	1.1847	0.8358	0.0357	0.0620	0.8131	1.0896	11.98
15	4.2224	2.8277	-0.0058	0.2097	0.4531	1.0325	0.0762	0.0766	0.7364	1.3460	17.48
16	4.3493	1.8253	0.0448	0.1353	0.2294	0.6665	0.0763	0.0494	0.8599	0.8689	10.98
17	0.6658	1.4428	0.0371	0.2393	0.2149	0.5269	0.0324	0.0874	0.5601	0.5330	28.20
18	1.7750	0.4334	-0.0200	0.1034	0.7705***	0.1583	-0.0148	0.0378	0.8110	0.5003	14.04

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE B-64. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, DRIVING CYCLE CO

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	14.8787	36.2887	-1.5669	6.5093	8.5362	13.2508	1.0956	2.3769	0.6444	14.8416	34.94
2	63.0070	38.7899	-3.0017	5.2216	-17.2291	14.1641	3.6264	1.9066	0.7408	10.6670	16.64
3	36.1581	34.0128	-1.3383	4.5992	-5.7169	12.4197	2.0622	1.6794	0.7040	9.7560	19.71
4	12.8002	36.8081	-2.2489	4.9993	-6.6945	13.4404	3.1958	1.8255	0.8459	11.0012	29.44
5	11.2317	49.8382	-2.7441	6.8084	-1.2721	18.1984	3.6704	2.4861	0.8499	15.7095	29.12
6	15.1234	31.9631	-1.6928	4.3476	-8.0791	11.6713	2.8169	1.5875	0.8176	9.6819	29.04
7	62.4222	37.8454	-3.6716	5.1402	-12.2013	13.8192	3.0494	1.8769	0.6840	11.3112	18.74
8	70.9620	45.6146	-5.1098	6.2044	-29.7545	16.6561	6.4066*	2.2655	0.8553	13.8171	18.45
9	24.9323	9.3779	-0.0039	0.6953	4.2614	3.4243	0.7240*	0.2539	0.9585	4.4641	7.63
10	-23.1271	20.6628	1.8000	1.5321	28.3859**	7.5450	0.0680	0.5594	0.9726	9.8360	10.01
11	6.4480	14.9302	1.1760	1.1338	6.8874	5.6517	-0.0586	0.4140	0.6131	8.6257	23.93
12	28.4447	23.1151	0.4138	1.7139	27.8075*	8.4404	1.1999	0.6258	0.9698	11.0033	7.79
13	2.1312	12.5280	-0.5601	0.9289	3.8503	4.5746	2.3869***	0.3362	0.9894	5.9636	7.42
14	27.7354	10.4632	0.2452	0.7758	22.2380***	3.8206	1.1264**	0.2833	0.9914	4.9811	4.07
15	54.7943	16.7169	-2.7095	1.2395	-13.7004	6.1041	4.0681***	0.4526	0.9877	7.9576	6.90
16	21.5895	31.9502	1.2252	2.3690	14.2802	11.6666	1.7110	0.8650	0.9377	15.2090	11.96
17	3.6237	21.5316	-0.8974	3.5707	-1.9987	7.8622	1.6450	1.3038	0.7150	7.9539	45.87
18	4.1491	9.0376	0.1656	2.1570	27.9330**	3.3000	-1.2240	0.7876	0.9253	10.4321	15.58

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE B-65. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, DRIVING CYCLE NO_x

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	-0.4608	0.5720	0.0511	0.1026	0.5696*	0.2089	0.0204	0.0375	0.9430	0.2340	15.52
2	-2.0014	0.9710	0.2207	0.1307	1.7330***	0.3546	-0.0927	0.0477	0.9676	0.2670	12.31
3	-1.0338	0.7185	0.1246	0.0972	1.4550***	0.2624	-0.0263	0.0355	0.9861	0.2061	6.80
4	-1.5521	0.9400	0.1668	0.1277	1.4940**	0.3422	-0.0934	0.0466	0.9436	0.2810	16.50
5	0.2038	0.7091	-0.0283	0.0969	0.5822*	0.2589	-0.0040	0.0354	0.9209	0.2235	16.12
6	-0.7488	0.4506	0.0722	0.0613	1.3406***	0.1645	-0.0416	0.0224	0.9910	0.1365	5.75
7	-0.4929	0.4129	0.0310	0.0561	0.6597***	0.1508	0.0202	0.0205	0.9879	0.1234	7.08
8	-1.7395	1.2708	0.1352	0.1728	1.2322*	0.4640	-0.0248	0.0631	0.9343	0.3849	20.62
9	-0.9212	0.3727	0.0472	0.0276	1.1650***	0.1361	-0.0243*	0.0101	0.9781	0.1774	9.75
10	-0.6062	0.4221	0.0490	0.0313	1.6705***	0.1541	-0.0428**	0.0114	0.9844	0.2010	7.10
11	-0.8890	0.9297	0.0490	0.0706	1.2465**	0.3395	0.0135	0.0258	0.9331	0.5371	16.68
12	-0.1535	0.1539	-0.0038	0.0114	0.3381***	0.0562	0.0035	0.004[illegible]	0.9809	0.0733	6.90
13	-0.1177	0.9869	0.0447	0.0732	1.3141**	0.3604	-0.0120	0.0267	0.9201	0.4698	14.01
14	-0.2941	0.1029	-0.0056	0.0076	0.1009*	0.0376	0.0152**	0.0028	0.9884	0.0490	5.11
15	-1.1657	1.0098	0.1127	0.0749	1.7404**	0.3687	-0.0670*	0.0273	0.8834	0.4807	19.31
16	-0.4943	0.3094	0.0456	0.0299	0.7097***	0.1130	-0.0302**	0.0084	0.9236	0.1473	16.37
17	-0.9241	0.3389	0.1253	0.0562	0.8336***	0.1237	-0.0284	0.0205	0.9820	0.1252	8.48
18	0.1075	0.1950	0.0045	0.0465	0.8375***	0.0712	-0.0177	0.0170	0.9601	0.2251	10.69

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE B-46. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, DRIVING CYCLE FUEL RATE

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	15.0451	22.3933	1.3876	4.0168	22.1821*	8.1769	1.3649	1.4667	0.9537	9.1586	9.53
2	44.2784	51.7084	2.1952	6.9605	15.3462	18.8812	2.0516	2.5416	0.9041	14.2196	10.54
3	52.2296	30.6485	-0.4860	4.1443	17.5177	11.1912	2.0037	1.5133	0.9630	8.7910	6.83
4	30.7537	30.8679	-0.0487	4.1925	19.7477	11.2714	1.8268	1.5309	0.9614	9.2258	8.19
5	38.5212	37.7220	-2.5686	5.1532	16.7326	13.7741	3.1836	1.8817	0.9562	11.8904	10.01
6	60.4860	39.8291	-1.3743	5.4175	17.0569	14.5435	2.4160	1.9782	0.9412	12.0646	8.83
7	76.4258	43.1397	-1.7244	5.8593	18.7096	15.7524	2.6898	2.1395	0.9447	12.8936	8.10
8	56.9679	40.2709	-1.7041	5.4776	-3.4904	14.7048	6.0871**	2.0001	0.9631	12.1984	8.40
9	33.5454	6.8489	0.2428	0.5078	27.8452***	2.5009	0.7033**	0.1854	0.9961	3.2602	2.54
10	-0.9232	19.0017	3.1587	1.4089	57.8498***	6.9384	0.1744	0.5145	0.9887	9.0452	4.78
11	47.0421	22.6618	0.4184	1.7209	27.1197*	8.2749	0.8097	0.6284	0.9431	13.0925	9.08
12	30.0019	16.7100	1.5521	1.2390	45.7890***	6.1016	0.7672	0.4524	0.9899	7.9543	4.22
13	33.8180	19.0605	0.6424	1.4133	34.4226***	6.9599	1.6108*	0.5160	0.9873	9.0732	5.06
14	76.6073	20.2609	-0.1764	1.5023	33.7734**	7.3982	1.3874*	0.5485	0.9830	9.6446	4.76
15	78.5374	29.5810	-0.5927	2.1933	20.4813	10.8014	2.5678*	0.8009	0.9708	14.0812	6.91
16	50.3635	25.4814	0.9581	1.8893	26.5962*	9.3045	1.4968	0.6899	0.9695	12.1297	6.87
17	28.6492	20.0163	-0.0921	3.3194	23.4714*	7.3089	2.1444	1.2121	0.9790	7.3942	6.27
18	60.0237	10.1014	0.2746	2.4109	54.8029***	3.6885	-1.7394	0.8803	0.9743	11.6600	6.23

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE B-67. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, SINUSOIDAL CYCLE HC

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	7.2902	3.5005	0.8502	0.6279	-0.7415	0.5629	-0.0739	0.1010	0.9171	0.7976	15.91
2	2.9134	5.8303	1.2759	0.7848	-0.4667	0.9376	-0.0982	0.1262	0.9149	0.8932	17.46
3	3.9412	4.8481	0.9928	0.6556	-0.4593	0.7797	-0.0962	0.1054	0.9210	0.7747	17.80
4	7.3849	2.1714	-0.3258	0.2949	-0.5204	0.3492	0.0397	0.0474	0.7081	0.3612	9.96
5	2.9877	2.6826	0.3287	0.3664	-0.2455	0.4314	-0.0315	0.0589	0.8402	0.4711	18.74
6	5.7337	7.4927	1.0771	1.0191	-0.4749	1.2049	-0.1114	0.1639	0.8447	1.2644	21.73
7	7.2231	7.7396	1.4570	1.0512	-1.0446	1.2447	-0.1187	0.1691	0.9230	1.2887	20.41
8	-1.3845	10.0611	5.4851**	1.3685	0.0476	1.6180	-0.6132*	0.2201	0.9745	1.6978	14.30
9	-7.6523	44.20348	1.8735	3.2775	0.0413	7.1087	-0.0963	0.5271	0.3373	11.7221	129.43
10	-0.0875	2.8992	0.8386*	0.2150	0.1835	0.4662	-0.0818	0.0346	0.9361	0.7688	14.15
11	-1.8833	2.4429	0.5460*	0.1855	0.5103	0.3929	-0.0587	0.0298	0.8088	0.7863	22.44
12	3.3690	6.3318	1.1426	0.4695	0.1055	1.0183	-0.1229	0.0755	0.8629	1.6791	18.35
13	-7.7273	6.5621	1.2625*	0.4865	1.1046	1.0553	-0.1454	0.0782	0.7741	1.7402	45.19
14	1.3100	3.2917	0.4893	0.2441	-0.5093	0.5294	-0.0181	0.0392	0.9133	0.8729	28.26
15	-2.9700	7.2139	1.5909*	0.5349	0.4331	1.1601	-0.1661	0.0860	0.8891	1.9130	26.64
16	-2.3291	11.4225	1.0608	0.8469	0.1196	1.8369	-0.0830	0.1362	0.6443	3.0291	54.74
17	0.8185	3.2558	1.4245*	0.5399	-0.1460	0.5236	-0.1567	0.0868	0.9373	0.6700	24.28
18	13.7430	2.6793	-1.3030	0.6395	-1.6829*	0.4309	0.1561	0.1028	0.8065	1.7229	62.45

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE B-40. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, SINUSOIDAL CYCLE CO

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	43.5751	24.3100	-6.7494	4.3606	-6.9453	3.9095	2.3383*	0.7013	0.9379	5.5388	13.59
2	16.8822	33.5366	6.1382	4.5144	2.1320	5.3933	-0.1348	0.7260	0.8104	5.1377	7.50
3	15.5063	101.0081	4.5346	13.6583	0.0004	16.2438	-0.2739	2.1965	0.1705	16.1402	44.29
4	-94.9727	46.0828	23.3484*	6.2590	13.2577	7.4109	-2.3947	1.0066	0.8935	7.6729	15.60
5	-104.2846	63.6435	21.8619	8.6943	9.1229	10.2349	-1.3648	1.3982	0.8806	11.1757	23.27
6	-106.7746	38.9838	25.5450**	5.3025	16.9111*	6.2693	-3.2240*	0.8527	0.9177	6.5784	16.77
7	-64.5196	39.9910	25.2942**	5.4316	9.7546	6.4312	-2.6606	0.8735	0.9523	6.6586	10.89
8	-118.0304	91.6492	30.5232	12.4660	16.5667	14.7387	-3.3234	2.0047	0.7876	15.4655	26.96
9	-15.6143	54.5872	4.8353	4.0474	3.6223	8.7785	-0.3567	0.6509	0.5771	14.4757	35.88
10	-47.4838	66.3694	6.6308	4.9210	5.0360	10.6733	-0.2200	0.7914	0.7763	17.6002	35.08
11	5.9948	16.3514	0.7580	1.2417	5.8614	2.6296	-0.0252	0.1997	0.8582	5.2627	10.86
12	23.5817	64.7952	6.2783	4.8043	10.1268	10.4202	0.0235	0.7726	0.8741	17.1828	10.36
13	-141.0860	81.2470	16.9118*	6.0241	19.0821	13.0659	-1.8798	0.9688	0.7791	21.5455	47.94
14	92.0072	74.7086	-0.2083	5.5393	-23.3805	12.0144	1.9912	0.8908	0.9336	19.8116	19.65
15	-313.4276	199.4076	37.3044	14.7852	47.2087	32.0681	-4.1864	2.3777	0.7261	52.8800	42.44
16	-132.7539	115.6017	20.0721	8.5714	14.4881	18.5907	-1.4341	1.3784	0.8456	30.6559	30.71
17	-89.2263	33.2796	24.2744**	5.5190	11.2209	5.3519	-2.7352*	0.8875	0.9095	6.8687	28.70
18	92.0660	32.2619	-10.3917	7.7000	-7.8901	5.1883	1.0907	1.2383	0.5427	20.7459	58.59

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE 8-69. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, SINUSOIDAL CYCLE NO_x

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	-8.6836	6.6330	1.4006	1.1898	2.0736	1.0667	-0.2162	0.1913	0.6728	1.5113	35.06
2	2.0830	6.4208	-0.2162	0.8643	-0.2408	1.0326	0.1046	0.1400	0.6796	0.9836	27.04
3	3.5181	6.8703	0.3376	0.9290	0.1129	1.1049	0.0266	0.1494	0.5311	1.0978	14.24
4	0.4919	4.0489	-0.0089	0.5499	0.3868	0.6511	0.0266	0.0884	0.7903	0.6741	17.30
5	2.8867	7.4780	-0.8317	1.0216	0.2580	1.2026	0.1298	0.1643	0.8014	1.3131	32.37
6	2.5117	3.5880	-0.1405	0.4880	0.2404	0.5770	0.0776	0.0785	0.9075	0.6055	9.63
7	5.2036	2.9414	-0.5210	0.3995	-0.3253	0.4730	0.1117	0.0642	0.8482	0.4897	11.33
8	9.9863	13.2577	-2.0382	1.8033	-0.5949	2.1321	0.3176	0.2900	0.7488	2.2372	40.94
9	-1.8775	8.6023	-0.0355	0.6378	1.2741	1.3834	0.0003	0.1026	0.6022	2.2812	42.75
10	-4.5206	13.6559	-0.3610	1.0126	1.9139	2.1961	0.0978	0.1628	0.7943	3.6214	36.84
11	-0.7201	2.0677	-0.0139	0.1570	0.2442	0.3325	0.0581	0.0253	0.9598	0.6655	13.96
12	-2.2916	3.5586	-0.1531	0.2639	1.0070	0.5723	0.0284	0.0424	0.9106	0.9437	23.78
13	7.6141	14.9061	-1.2180	1.1111	-0.5388	2.4100	0.2798	0.1787	0.7896	3.9741	38.83
14	0.9653	2.0404	-0.1141	0.1513	-0.0005	0.3281	0.0344	0.0243	0.8210	0.5411	25.39
15	16.0347	11.4521	-0.8692	0.8491	-1.6571	1.8417	0.1541	0.1366	0.2389	3.0369	44.69
16	3.0198	4.4158	-0.4450	0.3274	0.2614	0.7101	0.0715	0.0527	0.8379	1.1710	26.68
17	2.6172	2.4965	-0.3504	0.4140	-0.0540	0.4015	0.0760	0.0666	0.7614	0.5138	17.67
18	-6.0109	1.8170	0.4130	0.4337	2.0103***	0.2922	-0.1185	0.0697	0.9253	1.1684	21.93

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE B-70. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, SINUSOIDAL CYCLE FUEL RATE

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	16.7681	86.5670	5.6600	15.5280	15.3329	13.9214	0.4960	2.4972	0.8303	19.7235	12.74
2	99.3765	176.9246	-1.7780	23.8160	5.5845	28.4525	1.7626	3.8300	0.7266	27.1042	13.76
3	108.0672	56.6927	8.9750	7.6660	4.4851	9.1171	-0.1043	1.2328	0.8097	9.0590	4.64
4	26.2615	96.0212	16.4850	13.0417	13.4306	15.4418	-0.8074	2.0973	0.7743	15.9877	8.39
5	19.2564	94.2084	2.8332	12.8698	13.2906	15.1503	1.3896	2.0697	0.9214	16.5429	9.26
6	66.2307	60.6172	15.4997	8.2450	14.4107	9.7483	-0.9936	1.3259	0.8653	10.2289	4.63
7	160.1759	45.1817	8.9408	6.1366	9.2480	7.2660	-0.5382	0.9869	0.8339	7.5228	2.93
8	-17.3924	129.9892	16.9904	17.6809	18.8925	20.9045	-0.6386	2.8434	0.7873	21.9352	11.52
9	14.8527	73.8323	4.7343	5.4743	16.8810	11.8735	0.0635	0.8804	0.8658	19.5793	10.81
10	9.7369	107.3232	-0.3215	7.9575	26.9954	17.2594	1.0839	1.2797	0.9215	28.4606	11.37
11	104.8201	24.0018	-1.3294	1.8227	9.7437	3.8599	0.9110	0.2931	0.9809	7.7249	3.63
12	-0.1728	22.4994	3.8102	1.6683	37.1441***	3.6183	0.3488	0.2683	0.9963	5.9665	2.00
13	49.5107	116.8968	4.5325	8.6674	22.6114	18.7990	0.3384	1.3939	0.8411	30.9993	11.54
14	181.5764	132.2908	-6.6698	9.8088	5.8902	21.2746	2.1882	1.5774	0.8585	35.0186	11.74
15	15.6637	106.3050	19.7852	7.8820	26.0633	17.0956	-1.6314	1.2676	0.8379	28.1905	9.43
16	27.6083	35.1241	8.7094	2.6043	20.2541*	5.6486	-0.1945	0.4188	0.9767	9.3144	3.80
17	46.7091	76.4864	14.6512	12.6843	15.2210	12.3003	-0.8334	2.0398	0.7915	15.7403	8.11
18	57.5150	30.6469	-5.7390	7.3146	37.5507***	4.9285	0.2610	1.1763	0.9499	19.7073	7.23

Significance:* - 0.05
** - 0.01
*** - 0.001

TABLE B-71. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, STEADY STATE HC

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	0.4802	0.5316	0.0632	0.0954	-0.0021	0.0949	0.0252	0.0170	0.5650	0.4704	65.25
2	1.8854	1.8948	-0.1325	0.2551	-0.0349	0.3383	0.0425	0.0455	0.4800	1.1272	53.10
3	0.1534	0.4536	0.0335	0.0613	0.2740*	0.0810	-0.0052	0.0110	0.9119	0.2815	19.70
4	4.4831	3.1135	-0.3437	0.4229	-0.2333	0.5558	0.0470	0.0755	0.0681	2.0129	81.51
5	-1.4548	3.7121	0.4325	0.5071	1.4754*	0.6627	-0.1608	0.0905	0.3061	2.5311	82.52
6	6.1447	5.0941	-0.3090	0.6929	-0.7675	0.9094	0.0794	0.1237	0.0674	3.3379	108.96
7	1.1049	1.7802	-0.1276	0.2418	0.0204	0.3178	0.0490	0.0432	0.6191	1.1509	63.25
8	5.9020	2.7302	-0.3775	0.3714	-0.6053	0.4874	0.0751	0.0663	0.0796	1.7889	61.67
9	0.9755	0.5429	-0.0186	0.0403	0.1141	0.0970	0.0148	0.0072	0.8238	0.5590	27.12
10	1.0933	1.0615	0.0007	0.0787	0.3025	0.1895	0.0052	0.0141	0.6282	1.0931	40.52
11	0.4852	0.4814	0.0003	0.0366	0.2403*	0.0859	0.0101	0.0065	0.8491	0.6016	29.02
12	1.4284	0.9751	0.0013	0.0723	0.7198*	0.1741	0.0058	0.0129	0.9020	1.0041	20.42
13	0.5532	1.1516	-0.0340	0.0854	0.1863	0.2056	0.0200	0.0152	0.6834	1.1859	57.93
14	1.0249	1.9816	-0.0283	0.1469	-0.0785	0.3538	0.0284	0.0262	0.2833	2.0404	107.25
15	1.7029	0.6341	-0.0106	0.0470	0.0578	0.1130	0.0178*	0.0084	0.7650	0.6529	23.24
16	2.4008	2.3393	-0.0826	0.1734	-0.1344	0.4176	0.0380	0.0310	0.2920	2.4088	83.75
17	0.7636	0.2869	-0.1156*	0.0476	-0.1637**	0.0512	0.0343***	0.0085	0.5527	0.2293	92.95
18	1.2919	0.8635	-0.1826	0.2061	-0.0581	0.1542	0.0161	0.0368	0.0465	2.1561	281.54

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE B-72. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, STEADY STATE CO

Truck No,	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std, Error	Coefficient	Std, Error	Coefficient	Std, Error	Coefficient	Std, Error	r^2	Std, Dev.	Coeff. of Var.
1	12,8387	21,5769	-3,2533	3,8704	-4,0497	3,8521	1,4171	0,6910	0,4388	19,0892	176,01
2	51,5901	21,3036	-3,1034	2,8677	-3,4192	3,8033	1,1809*	0,5120	0,7362	12,6727	24,53
3	2,8256	9,7556	1,2691	1,3191	3,3675	1,7416	-0,1651	0,2355	0,6594	6,0530	28,13
4	-7,9322	14,6372	0,3810	1,9880	5,5167*	2,6132	0,0008	0,3549	0,8335	9,4633	49,88
5	75,7108	105,3846	-14,9127	14,3965	-24,0924	18,8142	5,7561*	2,5702	0,5319	71,8566	164,82
6	19,2489	15,7919	-2,4598	2,1480	-6,4467*	2,8193	1,4811***	0,3835	0,7827	10,3475	51,97
7	23,8397	64,3291	-2,9708	8,7372	-1,0927	11,4846	1,5550	1,5598	0,4845	41,5904	89,18
8	66,9604	17,3359	-2,9504	2,3580	-6,1676	3,0950	0,7882	0,4210	0,1737	11,3592	26,08
9	19,8117	36,9560	-0,9965	2,7401	2,4869	6,5977	0,4355	0,4892	0,4136	38,0542	90,11
10	-0,2086	36,2736	-0,5908	2,6895	7,2704	6,4759	0,2910	0,4802	0,5637	37,3514	92,77
11	16,3457	5,8088	-0,6351	0,4411	4,3411***	1,0370	0,2524**	0,0788	0,9405	7,2595	17,72
12	39,7044	78,0899	-0,7122	5,7900	26,9285	13,9413	0,3528	1,0337	0,6922	80,4103	47,84
13	35,9110	66,3513	-4,4840	4,9197	-5,0036	11,8456	1,7612	0,8783	0,5463	68,3230	124,38
14	36,7107	76,1079	-3,5860	5,6431	1,7508	13,5874	1,6438	1,0074	0,5850	78,3694	86,92
15	76,9631	35,6580	-3,4537	2,6439	-7,2332	6,3660	1,5949**	0,4720	0,7257	36,7176	40,77
16	56,5504	92,2243	-5,8231	6,8380	-6,5107	16,4647	2,3084	1,2208	0,5182	94,9647	115,28
17	47,1238	47,1511	-10,4032	7,8194	-16,9725	8,4178	4,0663	1,3960	0,5006	37,6780	237,47
18	-0,5441	22,8349	-0,6295	5,4501	10,1822*	4,0767	-0,7680	0,9730	0,2921	57,0176	166,01

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE B-73. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, STEADY STATE NO_x

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	-1.6036	1.2914	0.0888	0.2316	0.9791***	0.2305	-0.0255	0.0414	0.8891	1.1425	44.65
2	-3.3195	3.7979	0.1616	0.5112	1.6482*	0.6780	-0.0712	0.0913	0.7876	2.2592	80.75
3	0.1374	4.7259	-0.3889	0.6390	0.5520	0.8437	0.1758	0.1141	0.8541	2.9323	55.25
4	-1.2550	2.1309	-0.0161	0.2894	0.7340	0.3804	0.0200	0.0517	0.8567	1.3777	55.78
5	1.6057	2.6366	-0.2389	0.3602	-0.0234	0.4707	0.0844	0.0643	0.6193	1.7978	73.84
6	-1.3171	3.9317	-0.1393	0.5348	1.0691	0.7019	0.0716	0.0955	0.8482	2.5762	55.90
7	-0.3195	1.3949	-0.0870	0.1895	0.4508	0.2490	0.0513	0.0338	0.9249	0.9018	34.15
8	-4.5464	4.3516	0.1977	0.5919	2.0606**	0.7759	-0.0558	0.1057	0.8330	2.8514	68.95
9	-2.2317	1.4491	0.0508	0.1074	1.3432***	0.2587	-0.0088	0.0192	0.9092	1.4921	39.27
10	-3.1582	2.9725	0.0504	0.2204	2.0120***	0.5307	0.0037	0.0393	0.8694	3.0608	47.17
11	-0.7085	1.6486	-0.1036	0.1252	0.5091	0.2943	0.5911	0.0223	0.8505	2.0603	60.93
12	-0.3958	1.8548	0.0084	0.1375	0.4844	0.3311	0.0015	0.0246	0.5056	1.9099	99.78
13	-6.1710	4.0151	0.3342	0.2977	3.0460***	0.7168	-0.1014	0.0531	0.7406	4.1344	71.71
14	-0.4028	0.8262	0.4604	0.0613	0.3694*	0.1475	-0.0044	0.0109	0.6698	0.8508	54.74
15	-2.2429	1.7279	0.0996	0.1281	1.2228***	0.3085	-0.0240	0.0229	0.7987	1.7793	58.52
16	-1.7283	2.3884	0.1239	0.1771	0.9978*	0.4264	-0.0267	0.0316	0.5217	2.4594	90.12
17	-1.5694	2.2826	0.0435	0.3785	0.8474	0.4075	-0.0006	0.0676	0.7586	1.8240	76.80
18	-0.8673	0.6947	-0.0826	0.1658	0.9340***	0.1240	0.0085	0.0296	0.8168	1.7347	55.79

Significance: * - 0.05
** - 0.01
*** - 0.001

TABLE B-74. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 18 GASOLINE TRUCKS, STEADY STATE FUEL RATE

Truck No.	Constant		Load		Speed		Load x Speed		Goodness of Fit		
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error	r^2	Std. Dev.	Coeff. of Var.
1	44.9127	45.5329	-2.0111	8.1675	18.4085*	8.1289	1.0329	1.4581	0.8391	40.2833	29.02
2	50.8613	61.4037	-1.3200	8.2656	23.4119*	10.9623	1.1215	1.4757	0.9169	36.5266	20.36
3	61.3236	44.1309	-1.7069	5.9674	17.9267*	7.8786	1.1878	1.0653	0.9328	27.3818	16.59
4	29.0631	56.2200	-2.1672	7.6358	22.4137*	10.0369	1.0982	1.3632	0.9112	36.3477	24.80
5	49.5575	91.7587	-5.6288	11.1690	14.9656	14.5963	2.2941	1.9940	0.8253	55.7472	38.06
6	79.0829	51.5378	-3.9140	7.0101	13.1633	9.2010	2.1505	1.2515	0.9150	33.7697	19.17
7	76.8252	78.5669	-1.4643	10.6710	25.8522	14.0264	1.3052	1.9051	0.8767	50.7955	23.04
8	53.1119	65.0549	-2.9214	8.8487	18.6144	11.6142	1.4354	1.5797	0.8721	42.6267	26.87
9	21.0174	47.2430	-0.4493	3.5029	27.5665**	8.4342	0.3965	0.6254	0.8690	48.6468	30.80
10	67.8128	58.2851	-0.2825	4.3216	33.0907**	10.4056	0.4048	0.7715	0.8569	60.0171	25.93
11	82.2847	15.5042	-1.9454	1.1774	17.5241***	2.7679	0.8320***	0.2102	0.9684	19.3761	10.81
12	55.5732	60.1010	-0.3993	4.4562	44.2166***	10.7298	0.2116	0.7956	0.8941	61.8869	24.49
13	83.1367	33.6559	-1.3378	2.4954	26.8849***	6.0086	0.9103	0.4455	0.9485	34.6560	14.79
14	97.3336	40.2042	0.1696	2.9810	24.0584**	7.1776	0.7884	0.5322	0.9111	41.3989	16.66
15	122.7408	36.6860	-1.4733	2.7201	15.5736*	6.5495	1.1491*	0.4856	0.9079	37.7761	16.01
16	117.4684	46.5426	-3.6254	3.4509	9.6968	8.3092	1.7057*	0.6161	0.8723	47.9256	22.97
17	73.1570	76.1103	-7.7802	12.6219	14.6159	13.5879	3.2866	2.2534	0.8234	60.8190	34.65
18	75.9231	14.2665	1.4832	3.4050	39.1329***	2.5470	-0.9986	0.6079	0.9406	35.6226	14.83

Significance: * - 0.05
** - 0.01
*** - 0.001

APPENDIX C

DATA IN SUPPORT OF DIESEL TRUCK DATA ANALYSIS

TABLE C-1. COMPARISON OF CYCLE-TO-CYCLE AND TEST-TO-TEST VARIABILITY FOR HC FROM DIESEL TESTS

Avg. Speed	Load						
	Empty		Half		Full		
	Var.[a]	Sig.[b]	Var.	Sig.	Var.	Sig.	N
			Cycle-to-Cycle				
8 kph	0.146	*	0.119	*	0.075	**	4
16 kph	0.269	**	0.208	**	0.101	**	4
24 kph	0.039	n.s.	0.017	n.s.	0.068	*	4
32 kph	0.022	*	0.200	**	0.267	***	6
48 kph	0.000	n.s.	0.117	n.s.	0.401	**	4
64 kph	0.007	n.s.	0.000	n.s.	0.000	n.s.	4
All steady state	0.020	*	0.020	***	0.030	***	12
All sinusoidal	<0.010	n.s.	0.090	*	0.190	***	6
All driving	0.080	n.s.	0.060	n.s.	0.060	***	8
			Test-to-Test				
8 kph	0.003	n.s.	0.003	n.s.	0.004	n.s.	4
16 kph	0.003	n.s.	0.002	n.s.	0.001	n.s.	4
24 kph	0.015	n.s.	0.000	n.s.	0.011	n.s.	4
32 kph	0.002	n.s.	0.000	n.s.	0.018	**	6
48 kph	0.000	n.s.	0.000	n.s.	0.009	n.s.	4
64 kph	0.014	n.s.	0.000	n.s.	0.004	n.s.	4
All steady state	0.080	n.s.	0.060	**	0.070	*	12
All sinusoidal	0	n.s.	0.090	n.s.	0.010	n.s.	6
All driving	0	n.s.	0	n.s.	<0.010	n.s.	8

---

[a] Variability: cycle-to-cycle = (MSC-MSE)/N; test-to-test = (MSR (T)-MSE)/2

[b] Significance:
* = 0.05
** = 0.01
*** = 0.001
n.s. = not significant

Note: 1. Where possible, as determined by significance of F ratio from truck by cycle interaction, the pooled MSE was used in the calculation.

2. Values of zero reflect negative estimates

3. MSC - mean square cycle value
MSE - mean square error
MSR(T) - mean square repeat value within truck
N - sample size

TABLE C-2. COMPARISON OF CYCLE-TO-CYCLE AND TEST-TO-TEST VARIABILITY FOR CO FROM DIESEL TESTS

Avg. Speed	Load						
	Empty		Half		Full		
	Var.[a]	Sig.[b]	Var.	Sig.	Var.	Sig.	N
			Cycle-to-Cycle				
8 kph	0.000	n.s.	0.466	*	2.93	*	4
16 kph	0.000	n.s.	2.103	*	15.778	**	4
24 kph	0.350	n.s.	9.744	***	41.352	*	4
32 kph	1.616	n.s.	10.883	***	39.708	***	6
48 kph	0.000	n.s.	0.256	*	64.622	**	4
64 kph	0.000	n.s.	0.000	n.s.	0.304	n.s.	4
All steady state	0.460	***	0.430	***	47.850	***	12
All sinusoidal	0.950	*	0	n.s.	30.12	**	6
All driving	2.960	*	6.79	***	21.42	***	8
			Test-to-Test				
8 kph	0.000	n.s.	0.095	n.s.	0.660	n.s.	4
16 kph	0.649	n.s.	0.000	n.s.	0.248	n.s.	4
24 kph	0.000	n.s.	0.000	n.s.	0.000	n.s.	4
32 kph	0.000	n.s.	0.048	n.s.	0.694	n.s.	6
48 kph	0.000	n.s.	0.074	n.s.	0.000	n.s.	4
64 kph	0.000	n.s.	0.238	n.s.	0.303	n.s.	4
All steady state	7.720	*	0	n.s.	0	n.s.	12
All sinusoidal	1.430	*	0	n.s.	1.370	n.s.	6
All driving	0.040	n.s.	0.070	n.s.	0.030	n.s.	8

---

[a] Variability: cycle-to-cycle = (MSC-MSE)/N; test-to-test = (MSR (T)-MSE)/2

[b] Significance:
* = 0.05
** = 0.01
*** = 0.001
n.s. = not significant

Note: 1. Where possible, as determined by significance of F ratio from truck by cycle interaction, the pooled MSE was used in the calculation.

2. Values of zero reflect negative estimates

3. MSC - mean square cycle value
MSE - mean square error
MSR(T) - mean square repeat value within truck
N - sample size

TABLE C-3. COMPARISON OF CYCLE-TO-CYCLE AND TEST-TO-TEST VARIABILITY FOR NO_x FROM DIESEL TESTS

Avg. Speed	Load						
	Empty		Half		Full		
	Var.[(a)]	Sig.[(b)]	Var.	Sig.	Var.	Sig.	N
			Cycle-to-Cycle				
8 kph	0.038	n.s.	1.083	**	5.169	**	4
16 kph	0.241	n.s.	6.437	**	19.098	*	4
24 kph	2.078	***	12.908	**	44.719	**	4
32 kph	4.302	**	90.180	***	55.965	***	6
48 kph	1.880	*	14.814	*	73.388	**	4
64 kph	0.440	n.s.	0.666	*	6.733	**	4
All steady state	20.550	***	66.530	***	244.18	***	12
All sinusoidal	8.500	***	7.440	***	14.43	***	6
All driving	5.840	***	15.540	***	31.86	***	8
			Test-to-Test				
8 kph	0.033	n.s.	0.000	n.s.	0.073	n.s.	4
16 kph	0.000	n.s.	0.000	n.s.	0.000	n.s.	4
24 kph	0.114	*	0.000	n.s.	0.000	n.s.	4
32 kph	0.000	n.s.	0.000	n.s.	0.122	n.s.	6
48 kph	0.000	n.s.	0.000	n.s.	0.427	n.s.	4
64 kph	0.000	n.s.	0.217	n.s.	0.163	n.s.	4
All steady state	0.270	**	0.080	n.s.	0.780	n.s.	12
All sinusoidal	0.860	**	1.690	*	0.380	n.s.	6
All driving	0.250	*	0.420	*	1.530	**	8

(a) Variability: cycle-to-cycle = (MSC-MSE)/N; test-to-test = (MSR (T)-MSE)/2

(b) Significance:
* = 0.05
** = 0.01
*** = 0.001
n.s. = not significant

Note: 1. Where possible, as determined by significance of F ratio from truck by cycle interaction, the pooled MSE was used in the calculation.

2. Values of zero reflect negative estimates

3. MSC - mean square cycle value
MSE - mean square error
MSR(T) - mean square repeat value within truck
N - sample size

TABLE C-4. COMPARISON OF CYCLE-TO-CYCLE AND TEST-TO-TEST VARIABILITY FOR FUEL RATE FROM DIESEL TESTS

Avg. Speed	Load						
	Empty		Half		Full		
	Var. [(a)]	Sig. [(b)]	Var.	Sig.	Var.	Sig.	N
			Cycle-to-Cycle				
8 kph	1505.2	***	481.3	*	0000.0	n.s.	4
16 kph	2395.8	**	366.4	*	82.0	n.s.	4
24 kph	0000.0	n.s.	356.4	**	3419.0	**	4
32 kph	111.7	n.s.	1334.3	***	6238.4	***	6
48 kph	0000.0	n.s.	0000.0	n.s.	2584.7	**	4
64 kph	32.1	n.s.	28.4	n.s.	0000.0	n.s.	4
All steady state	8569.7	***	15776.8	***	12967.3	*	12
All sinusoidal	7028.2	***	7362.6	***	9577.3	***	6
All driving	4056.5	***	6974.0	***	10814.3	***	8
			Test-to-Test				
8 kph	32.4	*	18.7	n.s.	56.0	n.s.	4
16 kph	0000.0	n.s.	6.3	n.s.	0000.0	n.s.	4
24 kph	40.5	n.s.	27.2	n.s.	23.1	n.s.	4
32 kph	49.8	n.s.	24.2	n.s.	24.7	n.s.	6
48 kph	0000.0	n.s.	32.8	n.s.	0000.0	n.s.	4
64 kph	116.8	n.s.	0000.0	n.s.	130.9	*	4
All steady state	129.0	*	11.9	n.s.	1157.8	n.s.	12
All sinusoidal	150.1	*	279.1	n.s.	98.4	n.s.	6
All driving	88.3	*	118.1	***	311.6	**	8

(a) Variability: cycle-to-cycle = (MSC-MSE)/N; test-to-test = (MSR (T)-MSE)/2

(b) Significance:
* = 0.05
** = 0.01
*** = 0.001
n.s. = not significant

Note: 1. Where possible, as determined by significance of F ratio from truck by cycle interaction, the pooled MSE was used in the calculation.

2. Values of zero reflect negative estimates

3. MSC - mean square cycle value
MSE - mean square error
MSR(T) - mean square repeat value within truck
N - sample size

TABLE C-5. COEFFICIENTS FOR STEPWISE MULTIPLE REGRESSION ANALYSIS
DIESEL TEST CYCLE HC EMISSIONS AS A FUNCTION OF 13 MODE HC EMISSIONS

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
EMPTY LOAD												
Transient												
10			0.7027	1								
15			0.7006	1								
20			0.8852	1								
Sinusoidal												
20	1.3684	2	0.7605	1								
30			1.2766	1								

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
EMPTY LOAD											
Transient											
10											0.925
15											0.950
20											0.922
Sinusoidal											
20											0.974
30											0.969

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
HALF LOAD												
Transient												
10			0.6373	1					0.3607	2		
15			0.8019	1								
20			0.7418	2					0.6607	1		
Sinusoidal												
20			1.1563	1								
30			2.1199	1								

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
HALF LOAD											
Transient											
10									*		0.990
15											0.919
20									-0.2864	3	0.973
Sinusoidal											
20											0.923
30									-0.4769	2	0.977

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
FULL LOAD												
Transient												
10			0.7099	1								
15			0.7402	1								
20									0.7374	1		
Sinusoidal												
20			1.0028	1								
30			1.1506	1								

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
FULL LOAD											
Transient											
10											0.952
15											0.982
20											0.890
Sinusoidal											
20											0.876
30											0.988

Note: Variables entered to 0.05 significance level

TABLE C-6. COEFFICIENTS FOR STEPWISE MULTIPLE REGRESSION ANALYSIS
DIESEL TEST CYCLE CO EMISSIONS AS A FUNCTION OF 13-MODE CO EMISSIONS

EMPTY LOAD

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
Transient												
10									0.1270	2	0.0173	1
15											0.0368	2
20									0.2099	1		
Sinusoidal												
20											0.0172	2
30							0.9264	1				

EMPTY LOAD

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
Transient											
10					0.3698	1					0.971
15					0.9537	1			-0.5954	3	0.966
20	0.0472	2			0.2961	3					0.956
Sinusoidal											
20					0.4790	1					0.973
30	0.0292	2					0.2202	3			0.980

HALF LOAD

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
Transient												
10	1.5590	3							0.1639	1		
15							0.8627	3	0.2907	1		
20									0.3992	2		
Sinusoidal												
20	1.1194	2							0.1953	2		
30												

HALF LOAD

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
Transient											
10	0.0665	2									0.969
15	0.0897	2									0.974
20	0.1396	1									0.966
Sinusoidal											
20					0.9060	1					0.971
30					0.6570	1					0.968

FULL LOAD

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
Transient												
10									0.2635	2		
15									0.6685	2		
20									0.6670	2		
Sinusoidal												
20									0.61090	2		
30									0.2586	2		

FULL LOAD

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
Transient											
10	0.1229	1									0.960
15	0.2054	1									0.977
20	0.2605	1									0.965
Sinusoidal											
20	0.2626	1	-0.4040	2							0.968
30	0.2020	1									0.964

Note: Variables entered to 0.05 significance level

TABLE C-7. COEFFICIENTS FOR STEPWISE MULTIPLE REGRESSION ANALYSIS DIESEL TEST CYCLE NO_x EMISSIONS AS A FUNCTION OF 13 MODE NO_x EMISSIONS

EMPTY LOAD

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
Transient												
10			1.1200	1								
15			1.6029	1								
20			1.9300	1								
Sinusoidal												
20			2.6357	1	-0.3996	[illegible]						
30	1.7385	3	1.3339	1								

EMPTY LOAD

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
Transient											
10	0.0345	2									0.990
15	0.0621	2									0.992
20	0.0592	1									0.992
Sinusoidal											
20	0.682	2									0.985
30			0.0956	3							0.992

HALF LOAD

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
Transient												
10	1.0653	2			0.1825	3			0.0973	1		
15	2.2731	2							0.2004	1		
20	2.6263	2							0.3025	1		
Sinusoidal												
20	2.7066	2										
30	1.6716	2										

HALF LOAD

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
Transient											
10											0.989
15											0.988
20											0.987
Sinusoidal											
20							0.6111	1			0.986
30							0.7020	1			0.976

FULL LOAD

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
Transient												
10	2.1820	2							0.1900	1		
15	2.8286	2							0.2779	1		
20	2.9252	1							0.3301	1		
Sinusoidal												
20	4.1039	2							0.6133	1		
30	3.6622	2										

FULL LOAD

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
Transient											
10											0.984
15											0.980
20											0.982
Sinusoidal											
20											0.986
30			0.2550	1							0.983

Note: Variables entered to 0.05 significance level

TABLE C-8. COEFFICIENTS FOR STEPWISE MULTIPLE REGRESSION ANALYSIS
DIESEL TEST CYCLE FUEL RATE AS A FUNCTION OF 13 MODE FUEL RATE

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
							EMPTY LOAD					
Transient												
10	2.3030	2									0.1000	1
15	5.9990	1										
20	6.8235	1			2.1239	2	-1.1685	3				
Sinusoidal												
20	7.2000	1										
30			2.1795	1								

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
							EMPTY LOAD				
Transient											
10											0.986
15											0.979
20											0.994
Sinusoidal											
20											0.985
30											0.982

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
							HALF LOAD					
Transient												
10											0.2524	1
15											0.3252	1
20												
Sinusoidal												
20							-1.1300	2				
30					1.2987	1						

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
							HALF LOAD				
Transient											
10											0.982
15											0.984
20	9.3204	1									0.986
Sinusoidal											
20	8.7590	1									0.983
30											0.976

Cycle	Idle		Mode 2		Mode 3		Mode 4		Mode 5		Mode 6	
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered
							FULL LOAD					
Transient											0.2971	1
10											0.3990	1
15									0.6660	1		
20												
Sinusoidal												
20					1.9669	1						
30												

Cycle	Mode 8		Mode 9		Mode 10		Mode 11		Mode 12		r^2
	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	Coeff.	Order Entered	
							FULL LOAD				
Transient											0.976
10											0.976
15											0.976
20											
Sinusoidal											0.988
20	1.2030	1	-1.0966	2							0.977
30											

Note: Variables entered to 0.05 significance level

TABLE C-9. REGRESSION COEFFICIENTS FOR REWEIGHTING 13-MODE HC EMISSIONS FROM 12 DIESEL TRUCKS

	Mode											Coef. of Deter.
	Idle (1,7,13)	2	3	4	5	6	8	9	10	11	12	r^2
						Full Load						
Transient												
10	0.327	0.501	0.000	0.000	0.0352	0.137	0.000	0.000	0.000	0.000	0.000	0.923
15	0.247	0.514	0.000	0.000	0.0535	0.184	0.002	0.000	0.000	0.000	0.000	0.950
20	0.286	0.273	0.000	0.000	0.320	0.121	0.000	0.000	0.000	0.000	0.000	0.927
Sinusoidal												
20	0.000	0.976	0.000	0.000	0.000	0.011	0.013	0.000	0.000	0.000	0.000	0.871
30	0.000	0.803	0.000	0.000	0.000	0.015	0.158	0.000	0.000	0.000	0.025	0.901
						Half Load						
Transient												
10	0.327	0.360	0.000	0.000	0.250	0.063	0.000	0.000	0.000	0.000	0.000	0.958
15	0.180	0.507	0.000	0.000	0.170	0.144	0.000	0.000	0.000	0.000	0.000	0.949
20	0.211	0.299	0.000	0.000	0.466	0.026	0.000	0.000	0.000	0.000	0.000	0.957
Sinusoidal												
20	0.000	0.908	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.092	0.911
30	0.000	0.803	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.197	0.920
						Empty Load						
Transient												
10	0.366	0.455	0.000	0.000	0.109	0.070	0.000	0.000	0.000	0.000	0.000	0.946
15	0.224	0.599	0.000	0.000	0.030	0.147	0.000	0.000	0.000	0.000	0.000	0.931
20	0.186	0.493	0.000	0.000	0.266	0.0256	0.000	0.000	0.000	0.000	0.000	0.949
Sinusoidal												
20	0.000	0.803	0.000	0.000	0.000	0.000	0.000	0.000	0.092	0.000	0.105	0.956
30	0.000	0.779	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.220	0.954

TABLE C-10. REGRESSION COEFFICIENTS FOR REWEIGHTING 13-MODE CO EMISSIONS FROM 12 DIESEL TRUCKS

	Mode											Coef. of Deter.
	Idle (1,7,13)	2	3	4	5	6	8	9	10	11	12	r^2
						Full Load						
Transient												
10	0.358	0.000	0.000	0.240	0.286	0.002	0.113	0.000	0.000	0.000	0.000	0.974
15	0.053	0.000	0.000	0.349	0.359	0.012	0.177	0.016	0.032	0.000	0.000	0.982
20	0.262	0.038	0.000	0.000	0.435	0.012	0.252	0.000	0.000	0.000	0.000	0.965
Sinusoidal												
20	0.511	0.000	0.054	0.000	0.251	0.067	0.118	0.000	0.000	0.000	0.000	0.941
30	0.252	0.000	0.000	0.306	0.174	0.031	0.236	0.000	0.000	0.000	0.000	0.950
						Half Load						
Transient												
10	0.569	0.000	0.000	0.051	0.195	0.015	0.042	0.000	0.128	0.000	0.000	0.972
15	0.271	0.000	0.000	0.202	0.243	0.021	0.067	0.000	0.197	0.000	0.000	0.982
20	0.163	0.398	0.000	0.000	0.310	0.019	0.110	0.000	0.000	0.000	0.000	0.955
Sinusoidal												
20	0.368	0.000	0.000	0.108	0.098	0.000	0.000	0.000	0.426	0.000	0.000	0.977
30	0.147	0.241	0.000	0.232	0.144	0.000	0.018	0.026	0.192	0.000	0.000	0.978
						Empty Load						
Transient												
10	0.509	0.000	0.000	0.119	0.098	0.005	0.021	0.000	0.247	0.000	0.000	0.976
15	0.481	0.000	0.000	0.000	0.067	0.017	0.024	0.000	0.410	0.000	0.000	0.953
20	0.393	0.009	0.000	0.202	0.173	0.007	0.038	0.000	0.178	0.000	0.000	0.964
Sinusoidal												
20	0.332	0.000	0.000	0.402	0.000	0.004	0.014	0.000	0.216	0.015	0.016	0.986
30	0.241	0.000	0.115	0.422	0.000	0.000	0.022	0.031	0.000	0.000	0.170	0.992

TABLE C-11. REGRESSION COEFFICIENTS FOR REWEIGHTING 13-MODE NO$_x$ EMISSIONS FROM 12 DIESEL TRUCKS

	Mode										Coef. of Deter. r^2
	Idle (1,7,13)	2	3	4	5	6	8	9	10	11	12	
						Full Load						
Transient												
10	0.233	0.588	0.000	0.000	0.128	0.000	0.037	0.013	0.000	0.000	0.000	0.980
15	0.132	0.414	0.000	0.000	0.171	0.000	0.082	0.000	0.000	0.000	0.201	0.975
20	0.000	0.660	0.000	0.000	0.201	0.000	0.014	0.000	0.000	0.000	0.000	0.975
Sinusoidal												
20	0.020	0.618	0.081	0.000	0.046	0.000	0.079	0.157	0.000	0.000	0.000	0.975
30	0.246	0.290	0.000	0.000	0.315	0.000	0.032	0.117	0.000	0.000	0.000	0.976
						Half Load						
Transient												
10	0.200	0.653	0.038	0.000	0.043	0.000	0.038	0.029	0.000	0.000	0.000	0.985
15	0.351	0.433	0.000	0.000	0.164	0.000	0.010	0.042	0.000	0.000	0.000	0.984
20	0.000	0.638	0.106	0.000	0.197	0.000	0.059	0.000	0.000	0.000	0.000	0.986
Sinusoidal												
20	0.000	0.575	0.108	0.000	0.000	0.000	0.000	0.153	0.000	0.164	0.000	0.985
30	0.000	0.025	0.343	0.000	0.138	0.000	0.000	0.025	0.000	0.306	0.162	0.972
						Empty Load						
Transient												
10	0.152	0.772	0.000	0.000	0.031	0.000	0.001	0.043	0.000	0.000	0.000	0.991
15	0.000	0.726	0.082	0.000	0.042	0.000	0.027	0.000	0.000	0.051	0.072	0.987
20	0.000	0.453	0.245	0.000	0.114	0.000	0.013	0.000	0.000	0.000	0.175	0.985
Sinusoidal												
20	0.000	0.568	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.077	0.296	0.973
30	0.000	0.546	0.088	0.000	0.088	0.000	0.025	0.000	0.000	0.221	0.032	0.977

TABLE C-12. REGRESSION COEFFICIENTS FOR REWEIGHTING 13-MODE FUEL RATE FROM 12 DIESEL TRUCKS

	Modes											Coef. of Deter. r^2
	Idle (1,7,13)	2	3	4	5	6	8	9	10	11	12	
						Full Load						
Transient												
10	0.673	0.046	0.000	0.000	0.070	0.205	0.000	0.000	0.000	0.000	0.000	0.977
15	0.520	0.044	0.000	0.000	0.235	0.192	0.000	0.000	0.000	0.000	0.010	0.978
20	0.000	0.481	0.000	0.000	0.430	0.088	0.000	0.000	0.000	0.000	0.000	0.980
Sinusoidal												
20	0.087	0.636	0.000	0.000	0.000	0.033	0.244	0.000	0.000	0.000	0.000	0.979
30	0.000	0.392	0.000	0.000	0.591	0.000	0.017	0.000	0.000	0.000	0.000	0.978
						Half Load						
Transient												
10	0.663	0.162	0.000	0.000	0.000	0.106	0.068	0.000	0.000	0.000	0.000	0.985
15	0.304	0.422	0.126	0.000	0.177	0.007	0.076	0.000	0.000	0.000	0.000	0.987
20	0.191	0.384	0.000	0.000	0.177	0.000	0.130	0.000	0.000	0.000	0.117	0.989
Sinusoidal												
20	0.558	0.000	0.000	0.000	0.000	0.000	0.221	0.000	0.000	0.000	0.221	0.984
30	0.000	0.471	0.000	0.000	0.237	0.000	0.093	0.000	0.000	0.000	0.199	0.980
						Empty Load						
Transient												
10	0.545	0.348	0.000	0.000	0.000	0.029	0.078	0.000	0.000	0.000	0.000	0.985
15	0.400	0.448	0.000	0.000	0.000	0.000	0.130	0.000	0.000	0.000	0.022	0.982
20	0.156	0.500	0.000	0.000	0.000	0.000	0.134	0.000	0.000	0.000	0.209	0.986
Sinusoidal												
20	0.299	0.156	0.000	0.000	0.000	0.000	0.110	0.000	0.000	0.000	0.435	0.975
30	0.000	0.757	0.000	0.000	0.000	0.000	0.168	0.000	0.000	0.075	0.000	0.984

TABLE C-13. REGRESSION COEFFICIENTS FOR DIESEL TEST CYCLE COMBINED EMISSIONS AND FUEL RATE AS A FUNCTION OF 13-MODE COMBINED EMISSIONS AND FUEL RATE, COEFFICIENTS CONSTRAINED TO BE POSITIVE

		Mode										
	Idle	2	3	4	5	6	8	9	10	11	12	r^2
						Empty Load						
Transient												
10	2.2954	0.1363	0.2602	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9877
15	3.2218	0.1694	0.2854	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9855
20	3.9815	0.3810	0.2642	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9901
Sinusoidal												
20	5.6197	0.3450	0.0000	0.0000	0.0000	0.0000	0.0080	0.0000	0.0000	0.0000	0.0000	0.9846
30	2.1419	0.8495	0.4222	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9874
						Half Load						
Transient												
10	2.4979	0.0000	0.3358	0.0000	0.0000	0.0268	0.0000	0.0000	0.0000	0.0000	0.0000	0.9878
15	2.7044	0.0484	0.5245	0.0000	0.0000	0.0209	0.0000	0.0000	0.0000	0.0000	0.0000	0.9892
20	3.9370	0.0393	0.6653	0.0000	0.0042	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9918
Sinusoidal												
20	4.2995	0.0000	0.2166	0.0000	0.0000	0.0000	0.0885	0.0000	0.0000	0.0000	0.0000	0.9862
30	2.8559	0.5963	0.6140	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9838
						Full Load						
Transient												
10	3.2771	0.0000	0.2538	0.0000	0.0155	0.0534	0.0000	0.0000	0.0000	0.0000	0.0000	0.9809
15	3.4165	0.0000	0.2668	0.0000	0.1084	0.0764	0.0000	0.0000	0.0000	0.0000	0.0000	0.9809
20	4.2445	0.1289	0.3407	0.0000	0.1455	0.0561	0.0000	0.0000	0.0000	0.0000	0.0000	0.9836
Sinusoidal												
20	3.2356	0.3060	0.2866	0.0000	0.0000	0.0490	0.0920	0.0000	0.0000	0.0000	0.0000	0.9805
30	2.5626	0.4034	0.9905	0.0000	0.0073	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9798

TABLE C-14. REGRESSION COEFFICIENTS FOR DIESEL TEST CYCLE COMBINED EMISSIONS AND FUEL RATE AS A FUNCTION OF 13-MODE COMBINED EMISSIONS AND FUEL RATE, COEFFICIENTS NORMALIZED TO SUM TO 1.0

		Mode									
	Idle	2	3	4	5	6	8	9	10	11	12
					Empty Load						
Transient											
5	0.9249	0.0454	0.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.8527	0.0506	0.0967	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.8763	0.0461	0.0776	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.8605	0.0824	0.0571	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sinusoidal											
20	0.9409	0.0578	0.0000	0.0000	0.0000	0.0000	0.0134	0.0000	0.0000	0.0000	0.0000
30	0.6275	0.2489	0.1237	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
					Half Load						
Trnasient											
5	0.8904	0.0000	0.1096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.8732	0.0000	0.1174	0.0000	0.0000	0.0094	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.8199	0.0147	0.1590	0.0000	0.0000	0.0063	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.8474	0.0085	0.1432	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sinusoidal											
20	0.9337	0.0000	0.0470	0.0000	0.0000	0.0000	0.0192	0.0000	0.0000	0.0000	0.0000
30	0.7023	0.1466	0.1510	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
					Full Load						
Transient											
5	0.9427	0.0000	0.0000	0.0000	0.0546	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.9104	0.0000	0.0705	0.0000	0.0043	0.0148	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.8832	0.0000	0.0689	0.0000	0.0280	0.0198	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.8635	0.0262	0.0693	0.0000	0.0296	0.0114	0.0000	0.0000	0.0000	0.0000	0.0000
Sinusoidal											
20	0.8152	0.0771	0.0722	0.0000	0.0000	0.0124	0.0232	0.0000	0.0000	0.0000	0.0000
30	0.6465	0.1018	0.2499	0.0000	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TABLE C-15. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 19 10MPH

TEST 62

PWR \ RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
-2	0	0	0	0	2	5	5	11	2	4	5	0	0	1	0	0	0	0
2	0	1	170	152	2	1	0	2	6	1	2	2	0	0	0	0	0	0
6	0	0	0	1	1	1	0	2	3	2	3	0	0	1	0	0	0	0
10	0	0	0	0	1	0	1	5	10	7	3	2	0	0	0	0	0	0
14	0	0	0	0	2	1	1	7	12	5	11	3	0	1	0	0	0	0
18	0	0	0	0	0	0	2	6	15	5	14	0	0	0	0	0	0	0
22	0	0	0	0	1	2	0	2	0	1	1	5	1	1	0	0	0	0
26	0	0	0	0	0	0	1	2	3	0	1	5	1	1	1	1	0	0
30	0	0	0	0	0	2	0	4	0	2	0	5	1	1	0	0	0	0
34	0	0	0	0	0	0	1	0	0	1	1	1	1	0	1	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	6	2	3	1	0	0	0
42	0	0	0	0	0	0	0	0	1	3	0	0	2	0	1	0	0	0
46	0	0	0	0	0	0	0	1	6	5	2	0	6	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	2	0	7	2	1	0	0	0
54	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	2	0	1	0	2	0	0	0
62	0	0	0	0	0	0	0	0	0	1	2	1	0	2	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0
70	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
94	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	1	0	0
98	0	0	0	0	0	0	0	0	0	0	0	2	2	1	3	0	0	0

TABLE C-16. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 28 16KPH RPM TEST 62 PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
-2	0	0	0	0	0	6	5	11	15	5	1	0	0	0	0	0	0	0
2	0	0	399	2	7	1	2	7	0	0	1	0	0	0	0	0	0	0
6	0	0	0	1	0	0	1	0	16	5	0	2	0	0	0	0	0	0
10	0	0	0	0	0	0	1	12	10	3	2	0	0	0	0	0	0	0
14	0	0	0	0	1	1	1	4	10	5	0	2	0	0	0	0	0	0
18	0	0	0	0	0	0	2	1	15	3	2	0	0	0	0	0	0	0
22	0	0	0	0	0	0	1	0	10	15	1	1	0	0	0	0	0	0
26	0	0	0	0	1	1	0	0	12	4	3	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	2	0	4	1	0	0	0	0	0	0	0
34	0	0	0	0	0	0	1	2	5	1	4	2	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	1	4	2	1	0	0	0	0	0	0
42	0	0	0	0	1	0	0	0	4	6	3	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	7	0	3	1	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	3	4	1	1	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	1	1	3	0	0	0	0	0	0	0
58	0	0	1	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0
62	0	0	0	1	0	0	0	0	0	2	2	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	1	1	3	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	1	5	4	0	0	0	0	0	0	0

TABLE C-17. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 21 10MPH TEST 62	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	3	7	12	12	0	0	2	1	0	0	0	0	0	0
	2	0	0	404	3	4	3	0	3	0	1	1	0	0	0	0	0	0	0
	6	0	0	0	1	0	2	0	1	5	3	0	1	0	0	0	0	0	0
	10	0	0	1	1	0	1	6	3	3	2	1	0	0	0	0	0	0	0
	14	0	0	0	0	0	1	6	10	2	1	1	0	0	0	0	0	0	0
	18	0	0	1	0	0	0	1	2	2	3	1	0	0	0	0	0	0	0
	22	0	0	0	1	0	1	2	2	4	6	3	0	0	0	0	0	0	0
	26	0	0	0	0	0	1	2	3	0	6	5	0	0	0	0	0	0	0
	30	0	0	0	0	1	0	1	2	0	5	2	1	0	0	0	0	0	0
	34	0	0	0	0	0	1	1	1	2	3	7	1	0	0	0	0	0	0
	38	0	0	0	0	1	0	1	2	10	1	1	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	3	1	1	0	4	0	0	0	0	0	0
	46	0	0	0	0	0	1	1	4	3	5	0	1	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	6	1	0	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	3	1	4	1	0	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
	62	0	0	0	0	0	2	0	1	3	1	2	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	1	0	1	3	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	1	0	2	1	1	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	1	2	1	3	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	3	4	2	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	1	0	2	4	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	1	0	0	2	5	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	1	0	2	2	1	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	2	0	13	12	0	0	0	0	0	0	0

TABLE C-18. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 22 10MPH TEST 62	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	0	1	6	5	6	0	0	0	0	0	0	0	0	0
	2	0	2	401	3	5	12	11	4	2	0	0	0	0	0	0	0	0	0
	6	0	0	0	1	0	1	5	4	3	0	0	0	0	0	0	0	0	0
	10	0	0	1	2	1	1	11	20	5	1	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	1	10	10	3	1	0	0	0	0	0	0	0	0
	18	0	1	1	0	1	1	5	9	3	1	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	2	0	0	2	1	0	0	0	0	0	0	0	0
	26	0	0	1	0	0	0	7	0	0	2	1	0	0	0	0	0	0	0
	30	0	1	0	0	1	0	2	5	0	1	0	0	0	0	0	0	0	0
	34	0	0	0	0	0	2	0	9	1	1	1	0	0	0	0	0	0	0
	38	0	0	0	0	0	2	1	4	1	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	3	4	0	1	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0
	50	0	0	1	0	0	0	3	1	1	0	0	1	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	4	0	2	1	1	0	0	0	0	0	0
	58	0	0	1	0	0	0	1	1	0	2	1	0	0	0	0	0	0	0
	62	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
	66	0	0	1	0	0	1	3	1	1	1	0	1	0	0	0	0	0	0
	70	0	0	0	0	0	0	1	2	0	1	0	1	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	3	1	0	1	0	0	0	0	0	0	0
	78	0	0	1	0	0	0	1	2	0	1	2	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0
	90	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
	94	0	0	0	0	0	1	2	3	3	2	1	1	0	0	0	0	0	0
	98	0	0	0	0	0	2	25	10	5	13	6	0	0	0	0	0	0	0

TABLE C-19. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 23 10MPH TEST 62	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	0	5	10	19	17	2	2	0	0	0	0	0	0	0
	2	4	309	23	3	4	0	3	5	9	2	3	1	0	0	0	0	0	0
	6	0	0	0	0	0	2	2	6	5	3	2	1	0	0	0	0	0	0
	10	0	0	0	0	0	0	4	7	12	1	0	1	0	0	0	0	0	0
	14	0	0	1	0	0	0	0	3	0	4	0	1	0	0	0	0	0	0
	18	0	0	0	0	0	1	0	1	6	10	1	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	0	0	12	1	2	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	1	5	10	1	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	1	0	3	0	1	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	0	2	6	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	1	0	3	0	1	0	0	0	0	0	0	0
	42	0	0	0	0	1	0	0	0	1	0	1	2	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	0	1	4	1	2	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	1	6	3	1	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	0	3	2	0	1	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	4	4	1	2	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	0	0	7	4	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	0	1	3	1	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	1	7	0	2	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0

TABLE C-20. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 24 10MPH TEST 62	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	0	2	10	0	14	2	0	0	0	0	0	0	0	0
	2	0	2	409	3	7	0	0	3	6	2	0	0	0	0	0	0	0	0
	6	0	0	0	0	1	0	0	1	5	4	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	1	2	1	2	0	0	0	0	0	0	0	0
	14	0	0	0	1	1	0	2	7	0	0	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	0	5	15	7	2	0	0	0	0	0	0	0
	22	0	0	0	0	1	0	0	2	9	7	0	0	0	0	0	0	0	0
	26	0	0	0	0	1	0	0	3	7	7	3	0	1	0	0	0	0	0
	30	0	0	1	0	0	0	0	2	2	2	2	1	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	0	4	13	1	0	1	0	0	0	0	0
	38	0	0	0	0	0	0	1	0	4	14	1	1	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	0	2	5	4	1	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	1	3	4	0	3	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	1	1	2	1	1	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	1	4	0	1	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	0	4	3	0	1	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	1	2	4	0	2	2	0	0	0	0	0
	70	0	0	0	0	0	0	0	1	0	6	1	1	0	0	0	0	0	0
	74	0	0	0	1	0	0	0	0	1	1	1	1	0	0	0	0	0	0
	78	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0
	86	0	0	0	1	0	0	0	0	1	3	1	0	0	0	0	0	0	0
	90	0	0	0	2	0	0	0	0	0	2	0	1	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	0	0	17	20	0	0	0	0	0	0	0

TABLE C-21. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 24 10MPH	RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
TEST 62P	PWR -2	0	0	0	0	0	4	7	9	4	1	0	0	0	0	0	0	0	0
	2	0	32	379	3	5	0	0	1	5	0	0	0	0	0	0	0	0	0
	6	0	0	1	0	0	0	0	1	7	1	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	4	4	0	1	0	0	0	0	0	0
	14	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0
	18	0	0	0	0	1	0	1	1	12	6	1	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	0	9	9	1	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	1	0	6	5	0	0	0	0	0	0	0
	30	0	0	0	0	0	1	0	2	10	10	2	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	2	5	0	2	0	1	0	0	0	0	0
	38	0	0	0	0	0	1	1	1	7	10	2	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	6	4	4	3	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	2	10	10	1	2	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	4	3	1	0	1	0	0	0	0	0
	54	0	0	0	0	0	0	0	1	1	1	2	1	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	1	0	3	3	2	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	1	3	1	0	2	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	2	2	2	1	2	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	3	1	2	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	1	4	1	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	0	3	22	24	3	0	0	0	0	0	0

TABLE C-22. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 25 10MPH	RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
TEST 62	PWR																		
	-2	0	0	0	0	2	3	10	13	11	2	1	0	0	0	0	0	0	0
	2	0	1	404	4	1	0	2	1	3	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	1	2	2	5	3	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	3	0	2	2	0	0	0	0	0	0	0	0
	14	0	0	1	0	0	1	0	2	3	2	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	1	5	4	3	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	1	0	3	2	3	1	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	1	2	1	4	3	1	0	0	0	0	0	0	0
	30	0	0	0	0	1	0	1	1	3	1	1	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	2	10	4	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	1	1	0	6	11	2	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	1	6	6	1	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	1	1	0	3	2	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	1	3	5	3	0	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0
	58	0	0	0	0	0	1	0	0	2	3	1	0	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	1	3	0	2	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0
	70	0	0	0	0	0	1	0	0	3	3	1	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
	98	0	0	0	0	0	1	0	1	15	23	20	0	0	0	0	0	0	0

TABLE C-23. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 2A 10MPH TEST [illegible]	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	0	5	4	6	9	0	1	0	0	0	0	0	0	0
	2	0	2	402	4	3	0	1	0	1	0	0	0	0	0	0	0	0	0
	6	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	3	1	1	0	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	1	1	2	1	0	1	0	0	0	0	0	0	0
	18	0	0	0	1	0	0	7	0	2	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	6	5	2	1	0	0	0	0	0	0	0	0
	26	0	0	2	0	0	0	2	0	4	4	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	1	4	5	5	0	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	2	5	2	1	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	1	6	3	2	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	2	11	11	1	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	2	0	4	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	2	4	7	0	0	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	1	3	2	1	0	0	0	0	0	0	0
	62	0	0	0	0	0	0	1	2	6	5	1	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	10	4	2	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	1	2	7	0	0	0	0	0	0	0	0
	82	0	0	0	0	0	1	0	1	0	4	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	2	1	3	0	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	3	4	10	35	26	0	0	0	0	0	0	0

TABLE C-24. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH

TRUCK 25 10MPH TEST 82A	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	1	3	5	11	10	13	4	0	0	0	0	0	0	0
	2	0	2	442	5	3	2	2	3	1	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	2	0	1	2	1	0	0	0	0	0	0	0	0
	10	0	0	1	0	0	7	3	4	1	1	1	0	0	0	0	0	0	0
	14	0	0	0	0	0	0	0	15	2	3	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	1	0	5	1	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	1	2	2	1	2	0	0	0	0	0	0	0
	26	0	0	0	0	1	0	4	2	1	1	3	0	0	0	0	0	0	0
	30	0	0	0	0	1	0	1	9	3	0	2	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	2	0	1	5	1	0	0	0	0	0	0	0
	38	0	0	0	0	0	1	0	5	11	3	1	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	9	1	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	2	4	3	0	0	0	0	0	0	0	0
	54	0	0	0	0	0	0	1	0	5	0	1	0	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0
	62	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
	70	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
	98	0	0	0	1	0	0	0	12	14	20	14	0	0	0	0	0	0	0

TABLE C-25. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 26 16MPH	RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
TEST 62	PWR -2	0	0	1	1	6	4	9	15	13	7	3	3	0	0	0	0	0	0
	2	0	302	21	0	0	1	1	5	2	0	0	1	0	0	0	0	0	0
	6	0	0	0	0	0	0	1	3	4	1	2	0	0	0	0	0	0	0
	10	0	0	0	1	0	0	2	12	4	4	3	0	0	0	0	0	0	0
	14	0	0	0	1	0	0	1	10	5	1	7	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	0	9	5	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	4	3	7	1	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	9	0	7	1	0	0	0	0	0	0	0
	30	0	1	0	0	0	0	0	4	9	11	2	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	1	5	4	15	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	1	5	3	5	1	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	4	2	1	1	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	2	1	3	2	3	0	0	0	0	0	0	0
	50	0	0	1	1	0	0	0	2	4	4	2	0	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	2	2	4	1	0	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	3	2	3	0	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	2	0	2	1	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	3	1	2	0	1	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	1	1	2	1	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	2	2	1	2	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	2	2	1	2	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	2	1	1	2	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	3	7	4	3	0	0	0	0	0	0	0

TABLE C-26. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 27 10MPH TEST 62	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	2	4	4	0	10	19	12	4	2	1	0	0	0	0	0
	2	0	0	454	6	0	0	0	3	6	2	4	1	0	0	0	0	0	0
	6	0	0	0	2	0	0	0	6	10	4	0	3	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	2	13	3	2	4	0	0	0	0	0	0
	14	0	0	0	0	0	5	0	0	10	11	6	1	1	0	0	0	0	0
	18	0	0	0	0	0	0	0	1	6	13	3	3	0	0	0	0	0	0
	22	0	0	0	0	0	0	1	0	6	10	3	2	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	1	7	0	5	1	0	0	0	0	0
	30	3	0	0	0	0	0	0	0	1	4	2	4	2	0	0	0	0	0
	34	0	0	0	0	0	0	0	0	3	3	1	0	1	0	0	0	0	0
	38	0	0	0	0	0	0	0	0	2	4	1	2	0	1	0	0	0	0
	42	0	0	0	0	0	0	0	3	1	3	2	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	1	0	3	0	1	1	0	0	0	0	0
	50	0	0	0	0	0	0	0	1	3	0	0	0	2	1	0	0	0	0
	54	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0
	62	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0
	66	0	0	0	0	0	0	0	1	0	0	0	2	1	0	0	0	0	0
	70	0	0	0	0	0	0	0	1	1	0	4	3	4	0	0	0	0	0
	74	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
	82	6	0	0	0	0	0	0	0	3	1	0	0	0	3	0	0	0	0
	86	0	0	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0
	90	0	3	0	0	0	0	0	1	2	0	0	2	4	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	0	0	0	4	3	6	0	0	0	0
	98	0	0	0	0	0	0	0	1	3	1	10	1	0	0	0	0	0	0

TABLE 9-37. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

[illegible] RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
<2	0	0	0	1	3	3	5	15	10	27	91	2	9	0	0	0	0	0
2	0	0	37	292	0	0	0	2	7	15	1	1	0	0	0	0	0	0
6	0	0	0	0	0	0	2	6	4	7	3	0	0	0	0	0	0	0
10	0	0	0	1	0	0	0	13	5	6	4	0	1	0	0	0	0	0
14	0	0	0	1	0	0	1	5	4	4	4	3	0	0	0	0	0	0
18	0	0	0	0	0	1	1	3	1	2	5	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	2	3	7	3	1	0	0	0	0	0	0
26	0	0	0	1	0	0	0	2	1	2	9	1	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0
34	0	0	0	0	2	0	0	2	1	1	4	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	4	4	3	2	1	0	0	0	0	0
42	0	0	0	0	0	0	2	0	2	5	0	1	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	2	0	2	1	1	0	0	0	0	0
50	0	0	0	0	0	1	0	3	2	1	1	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	1	0	3	1	1	0	0	0	0	0	0
58	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	1	1	2	1	1	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	1	4	3	0	3	0	0	0	0	0	0

TABLE C-20. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 29 10MPH TEST 02 RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
-2	0	0	0	2	4	0	12	10	0	3	4	0	0	0	0	0	0	0
2	0	1	330	7	0	1	2	2	4	1	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	4	1	1	0	1	0	0	0	0	0	0
10	0	0	0	1	0	0	0	0	4	17	0	1	0	0	0	0	0	0
14	0	0	0	0	0	0	0	12	2	11	1	0	1	0	0	0	0	0
18	0	0	0	0	1	0	1	19	3	5	10	1	0	0	1	0	0	0
22	0	0	0	0	1	1	0	5	2	3	4	2	0	0	0	0	0	0
26	0	0	0	0	0	0	0	5	4	2	1	2	0	0	0	0	0	0
30	0	0	0	0	0	0	0	2	4	2	1	0	0	2	2	0	0	0
34	0	0	0	0	0	1	0	2	7	0	1	1	1	0	0	0	0	0
38	0	0	0	0	0	0	1	3	1	3	3	1	0	0	1	0	0	0
42	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
46	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0
50	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
54	0	0	0	0	0	0	0	0	4	0	2	2	3	0	3	0	0	0
58	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	1	0	0	4	1	0	1	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	2	0	3	1	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	5	0	0	0	1	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	1	2	0	3	0	1	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0	2	1	1	1	1	0	0	0	9
98	0	0	0	0	0	0	0	0	0	1	2	2	9	7	1	0	0	0

TABLE C-29. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 16 KPH CYCLE

TRUCK 30 10MPH
TEST 62

RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
-2	0	0	0	5	9	14	15	6	11	0	0	0	0	0	0	0	0	0
2	0	278	52	1	0	1	4	0	0	1	0	0	0	0	0	0	0	0
6	0	0	0	0	1	1	4	0	3	2	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	8	7	12	2	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	6	19	87	3	0	1	0	0	0	0	0	0
18	0	0	0	0	0	0	10	3	20	2	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	16	2	5	6	1	1	1	0	0	0	0	0
26	0	0	0	0	0	0	1	0	2	1	0	2	0	0	0	0	0	0
30	0	0	0	0	0	0	5	0	2	1	2	0	0	0	0	0	0	0
34	0	0	0	0	0	1	1	1	6	0	6	0	2	0	0	0	0	0
38	0	0	0	0	0	1	0	0	3	1	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	1	0	4	2	2	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	2	0	3	2	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	3	2	1	2	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	2	0	2	2	0	2	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
62	0	0	0	0	0	0	0	0	1	2	4	2	1	2	0	0	0	0
66	0	0	0	0	0	0	0	1	1	1	2	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	1	0	0	2	1	1	0	0	0	0
74	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	1	2	1	2	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0	2	3	1	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0	0	4	1	2	0	0	0	0	0

TABLE C-30. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 19 20MPH TEST 64	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	2	3	0	12	11	13	9	0	6	0	0	0	0	0
	2	5	0	216	49	2	0	0	0	1	0	2	1	3	0	0	0	0	0
	6	0	0	0	0	0	0	1	1	0	2	3	2	1	1	0	0	0	0
	10	0	0	0	1	2	1	0	1	0	2	3	1	0	2	0	0	0	0
	14	0	0	0	0	0	1	0	1	1	3	6	3	3	0	0	0	0	0
	18	0	0	0	0	0	1	0	0	0	3	6	4	1	3	0	0	0	0
	22	0	0	0	0	1	0	0	0	1	13	5	2	0	2	0	0	0	0
	26	0	0	0	0	0	0	1	0	0	0	7	6	0	0	0	0	0	0
	30	0	0	1	0	0	0	0	1	2	5	3	2	2	0	0	0	0	0
	34	6	0	0	0	0	0	0	0	1	7	2	9	5	4	1	0	0	0
	38	0	0	0	0	0	0	0	0	1	2	1	4	2	0	0	1	0	0
	42	0	0	0	0	0	0	0	0	0	2	3	3	4	1	0	0	0	0
	46	0	0	0	0	0	0	0	0	0	5	1	2	1	2	1	1	0	0
	50	0	0	0	0	0	0	0	0	0	1	2	0	1	0	0	1	0	0
	54	0	0	0	0	0	0	0	0	0	4	6	2	3	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	0	0	2	3	2	2	0	0	0	0
	62	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0
	66	0	0	0	0	0	0	0	0	0	1	1	0	3	0	1	0	0	0
	70	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	0	0	1	0	1	4	2	0	0	0
	78	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0
	82	0	0	0	0	0	0	0	0	0	0	1	0	2	1	1	0	0	0
	86	0	0	0	0	0	0	0	0	0	0	0	1	0	3	1	0	0	0
	90	0	0	0	0	0	0	0	0	0	0	1	1	0	5	3	0	0	0
	94	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	0	0	0
	98	0	0	0	0	0	0	0	0	0	0	3	9	22	36	25	1	0	0

TABLE C-31. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 26 20MPH RPM TEST 64 PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
-2	0	0	0	0	0	0	10	12	10	2	1	1	0	0	0	0	0	0
2	0	0	217	0	0	0	2	6	5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	10	6	0	1	0	0	0	0	0	0	0
10	0	0	0	0	1	0	3	7	0	3	0	0	0	0	0	0	0	0
14	0	0	0	1	1	1	2	6	10	0	2	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	2	16	2	1	1	0	0	0	0	0	0
22	0	0	0	0	0	2	0	3	14	0	1	2	0	0	0	0	0	0
26	0	0	0	0	2	0	0	2	0	9	4	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	2	15	5	3	0	0	0	0	0	0	0
34	0	0	0	0	0	0	1	0	5	5	2	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	3	4	2	1	0	0	0	0	0	0
46	0	0	0	0	0	0	0	1	23	4	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	17	1	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	2	17	1	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	1	1	4	3	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	1	7	3	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	1	5	3	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0	0	1	0	10	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	2	17	6	0	0	0	0	0	0	0

TABLE C-32. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 21 20MPH
TEST 64

PWR \ RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
-2	0	0	0	0	4	6	0	11	11	2	1	0	0	0	0	0	0	0
2	0	0	225	5	4	0	2	1	4	2	0	0	0	0	0	0	0	0
6	0	0	0	0	0	2	6	2	4	0	2	0	0	0	0	0	0	0
10	0	0	0	0	0	2	0	0	12	2	2	0	0	0	0	0	0	0
14	0	0	1	1	0	3	1	0	9	4	1	1	0	0	0	0	0	0
18	0	0	1	0	1	1	1	0	10	3	1	0	0	0	0	0	0	0
22	0	0	1	1	0	0	0	1	9	1	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	2	0	10	6	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	1	2	6	7	0	0	0	0	0	0	0	0
34	0	1	0	0	1	0	0	0	1	2	1	0	0	0	0	0	0	0
38	0	0	0	0	0	0	1	1	6	1	0	0	0	0	0	0	0	0
42	0	0	0	0	0	2	1	1	9	2	2	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	7	3	3	0	0	0	0	0	0	0
50	0	0	1	0	0	0	0	2	0	2	2	0	0	0	0	0	0	0
54	0	1	0	0	0	0	0	0	4	7	1	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	1	0	10	1	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	13	1	0	2	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	5	2	3	1	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	4	9	2	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	2	6	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0	1	3	2	1	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	9	30	32	14	0	0	0	0	0	0	0

TABLE C-33. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 22 20MPH	RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
TEST 64	PWR																		
	-2	0	0	0	0	0	1	4	3	2	0	1	0	0	0	0	0	0	0
	2	0	1	223	5	5	11	0	2	1	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	1	10	4	3	0	0	0	0	0	0	0	0	0
	10	0	0	1	0	0	0	16	16	4	0	0	0	0	0	0	0	0	0
	14	0	0	0	0	1	0	5	4	7	1	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	3	1	10	0	0	0	0	0	0	0	0	0
	22	0	0	1	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0
	26	0	0	1	0	0	0	6	1	1	0	1	0	0	0	0	0	0	0
	30	0	0	0	0	2	0	5	1	2	1	0	0	0	0	0	0	0	0
	34	0	0	0	0	1	1	0	0	2	1	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	1	3	2	2	3	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	2	1	1	0	1	2	0	0	0	0	0	0	0
	50	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0
	54	0	0	0	0	0	3	2	0	0	2	1	0	0	0	0	0	0	0
	58	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0
	62	0	0	0	0	0	5	2	4	0	1	2	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	2	2	0	1	2	0	0	0	0	0	0	0
	70	0	0	0	0	0	2	2	2	1	0	1	1	0	0	0	0	0	0
	74	0	0	0	0	0	2	2	0	1	1	1	0	0	0	0	0	0	0
	78	0	0	0	0	0	2	7	1	1	2	1	0	0	0	0	0	0	0
	82	0	0	0	0	0	1	5	2	0	0	2	0	0	0	0	0	0	0
	86	0	0	0	0	0	1	1	1	0	2	0	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	1	1	0	1	3	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	1	14	1	0	5	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	31	65	15	12	13	0	0	0	0	0	0	0

TABLE C-34. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 23 20MPH	RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
TEST 64	PWR -2	0	0	0	0	0	0	14	11	10	1	0	0	0	0	0	0	0	0
	2	0	210	0	3	4	1	4	0	1	0	3	1	0	0	0	0	0	0
	6	0	0	1	0	0	0	5	19	0	1	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	6	9	7	2	0	1	0	0	0	0	0	0
	14	0	0	0	0	0	0	2	1	15	3	1	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	0	1	11	6	1	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	2	13	6	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	2	0	2	2	1	1	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0	3	4	3	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	0	2	11	1	1	0	0	0	0	0	0
	38	0	0	0	0	0	[illegible]	1	1	5	9	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	1	2	11	1	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	5	3	1	1	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	0	22	5	2	1	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	0	2	11	2	1	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	0	1	9	1	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	1	1	3	1	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	2	17	19	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	0	4	12	13	0	0	0	0	0	0	0

TABLE C-35. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 24 20MPH TEST 64	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	0	3	7	10	6	0	0	0	0	0	0	0	0	0
	2	0	5	215	4	7	0	0	2	4	0	0	1	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	4	2	2	0	0	0	0	0	0	0	0
	10	0	0	0	0	1	1	0	1	5	0	2	0	0	0	0	0	0	0
	14	0	0	0	1	0	0	0	2	17	2	0	0	0	0	0	0	0	0
	18	0	0	0	1	0	1	0	0	12	3	3	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	2	12	9	2	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	2	13	4	1	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	3	0	4	5	0	1	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	0	4	4	1	1	0	0	0	0	0	0
	38	0	0	1	0	0	1	0	2	2	11	2	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	1	5	0	1	1	0	0	0	0	0
	46	0	0	0	0	0	0	1	0	3	10	1	1	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	1	5	3	2	0	0	0	0	0	0
	54	0	0	1	0	0	0	0	0	16	5	0	2	1	0	0	0	0	0
	58	0	0	0	0	1	0	0	0	1	14	1	0	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	1	2	2	0	2	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	1	2	6	1	2	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	1	5	3	2	2	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	10	2	0	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	14	1	0	1	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	0	16	24	24	10	0	0	0	0	0	0

TABLE C-36. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 24 20MPH TEST 64R	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	0	6	6	0	3	0	0	0	0	0	0	0	0	0
	2	0	83	149	4	0	0	1	3	1	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
	10	0	1	0	0	0	0	2	1	3	0	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	1	6	5	4	1	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	1	2	14	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	1	1	0	4	7	3	1	0	0	0	0	0	0	0
	26	0	0	0	1	1	0	0	2	15	2	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	1	3	11	2	0	0	0	0	0	0	0	0
	34	0	0	0	0	0	1	0	0	6	10	1	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	0	0	5	7	0	1	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	2	6	2	1	0	0	0	0	0	0
	46	0	0	0	0	0	0	1	1	2	14	1	1	0	0	0	0	0	0
	50	0	0	0	0	0	1	0	1	1	9	0	0	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	0	3	4	0	1	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	12	6	1	2	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	0	3	5	0	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	0	15	7	1	1	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	7	4	2	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	5	2	1	2	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	9	3	1	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	1	5	3	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	6	1	2	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	4	4	1	2	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	12	1	0	1	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	2	27	26	20	5	0	0	0	0	0	0

TABLE C-37. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 25 20MPH TEST 64	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	1	7	5	12	9	3	0	0	0	0	0	0	0	0
	2	0	5	223	5	3	3	0	4	1	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	2	0	1	5	0	0	0	0	0	0	0	0	0
	10	0	0	0	1	0	7	2	3	0	1	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	5	4	9	1	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	1	2	11	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	1	2	12	4	0	0	0	0	0	0	0	0
	30	0	0	0	1	1	0	0	2	3	3	0	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	1	4	5	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	2	2	7	2	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	1	0	6	9	1	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	1	2	5	6	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	1	1	16	5	2	0	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
	58	0	0	0	0	0	0	1	1	1	2	0	0	0	0	0	0	0	0
	62	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	0	0	10	1	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	16	0	0	2	0	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	6	0	5	1	2	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	1	0	2	3	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	1	0	2	1	3	0	0	0	0	0	0	0
	90	0	0	0	0	0	1	0	2	0	5	1	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	11	13	16	37	23	0	0	0	0	0	0	0

TABLE C-38. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 25 20MPH	RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
TEST 64R	PWR -2	0	0	0	0	4	4	6	0	6	4	2	0	0	0	0	0	0	0
	2	0	0	224	6	2	0	0	4	1	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	2	6	1	1	1	0	0	0	0	0	0	0	0
	18	0	0	1	0	1	1	4	1	2	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	1	1	11	1	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	2	3	2	15	2	1	0	0	0	0	0	0	0
	30	0	0	0	0	3	1	1	3	10	1	1	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	6	4	0	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	1	5	3	2	0	0	0	0	0	0	0	0
	42	0	0	0	0	1	2	0	2	6	0	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	1	0	0	5	10	2	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	7	5	2	6	0	0	0	0	0	0	0
	54	0	0	0	1	0	0	0	1	5	2	1	0	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	2	9	2	1	0	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	4	7	0	0	0	0	0	0	0	0	0
	66	0	6	0	0	0	0	0	7	1	5	1	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	5	0	4	0	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	4	2	0	1	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	11	0	3	1	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	0	9	1	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	10	0	3	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	5	42	46	26	0	0	0	0	0	0	0

TABLE C-39. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 25 20MPH TEST 64A	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	0	2	9	13	20	9	2	0	0	0	0	0	0	0	0
	2	0	1	200	3	4	1	5	3	4	1	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0
	10	0	0	1	0	0	0	10	7	2	0	0	0	0	0	0	0	0	0
	14	0	0	0	1	0	0	4	6	5	1	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	1	3	5	2	0	0	0	0	0	0	0	0
	22	0	0	0	0	1	1	0	4	0	1	1	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	1	3	7	1	19	0	0	0	0	0	0	0
	30	0	0	0	0	0	1	1	4	15	4	1	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	1	5	5	2	1	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	0	3	10	17	1	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	3	7	2	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	1	1	13	13	1	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	12	7	2	0	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	4	4	2	1	0	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	2	2	17	1	0	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	1	3	16	0	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	0	11	2	2	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	7	2	2	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	1	7	2	3	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	1	6	0	2	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	0	35	30	21	0	0	0	0	0	0	0

TABLE C-40. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 26 20MPH	RPM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
TEST 64	PWR																		
	-2	0	0	0	4	7	7	11	13	9	0	0	0	0	0	0	0	0	0
	2	0	214	14	0	0	0	1	3	2	0	0	0	0	0	0	0	0	0
	6	0	0	1	0	0	2	0	2	1	2	1	0	0	0	0	0	0	0
	10	0	0	0	0	0	5	3	5	4	3	4	0	0	0	0	0	0	0
	14	0	0	1	0	0	2	0	3	9	4	2	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	0	1	20	2	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	4	4	0	2	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	1	4	3	2	0	0	0	0	0	0	0	0
	34	0	0	0	0	0	1	1	5	4	4	1	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	1	11	5	4	2	0	0	0	0	0	0	0
	42	0	0	0	0	0	1	1	8	3	5	3	1	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	7	5	2	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	1	0	10	2	0	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	1	1	3	0	0	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	1	1	6	0	1	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	2	2	4	1	0	0	0	0	0	0	0
	66	0	0	0	0	0	0	0	21	2	1	3	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	4	4	3	2	0	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	4	2	1	2	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	1	18	1	1	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	3	4	1	0	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	5	27	21	5	0	0	0	0	0	0	0

TABLE C-41. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 27 20MPH TEST 64	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	3	4	0	5	11	14	13	12	3	0	0	0	0	0	0
	2	0	0	221	6	0	0	0	5	3	3	0	1	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	4	10	1	2	3	2	0	0	0	0	0
	10	0	0	0	1	0	0	1	1	16	5	0	2	1	0	0	0	0	0
	14	0	0	0	0	0	0	2	0	5	2	1	3	0	0	0	0	0	0
	18	3	0	0	0	0	0	0	0	4	0	3	4	1	0	0	0	0	0
	22	0	0	0	0	0	0	0	1	1	10	0	2	0	0	0	0	0	0
	26	0	0	0	0	0	0	2	0	2	3	2	5	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0	2	10	1	6	2	0	0	0	0	0
	34	0	0	0	0	0	0	1	0	0	7	2	4	0	0	0	0	0	0
	38	0	0	0	0	4	0	0	1	0	1	1	3	1	0	0	0	0	0
	42	0	0	0	0	4	0	0	0	1	5	0	2	1	1	0	0	0	0
	46	0	0	0	0	0	0	0	0	0	4	1	2	0	1	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	4	1	2	0	1	0	0	0	0
	54	0	0	0	0	0	0	0	0	0	7	2	1	1	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	0	6	0	2	2	0	0	0	0	0
	62	0	0	0	0	0	0	0	0	0	1	1	1	2	1	0	0	0	0
	66	0	0	0	6	0	0	0	0	1	1	1	2	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	0	2	1	3	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	0	2	2	3	0	1	0	0	0	0
	90	0	0	0	0	0	0	0	0	0	1	3	3	0	1	0	0	0	0
	94	0	0	0	0	0	0	0	0	0	4	12	3	0	2	0	0	0	0
	98	0	0	0	0	0	0	0	0	0	26	25	21	2	0	0	0	0	0

TABLE C-42. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 28 20MPH TEST 64	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	3	7	4	11	26	26	21	8	3	0	0	0	0	0	0
	2	0	0	7	110	0	1	4	3	5	5	0	0	0	0	0	0	0	0
	6	0	0	1	2	0	0	2	3	5	15	3	1	0	0	0	0	0	0
	10	0	0	0	1	1	0	1	10	7	22	0	2	1	0	0	0	0	0
	14	0	0	1	0	0	0	2	3	10	20	13	2	0	0	0	0	0	0
	18	0	0	0	0	0	0	0	4	9	5	14	3	1	0	0	0	0	0
	22	0	0	0	2	0	0	0	0	15	5	23	2	0	0	0	0	0	0
	26	0	0	0	0	1	0	0	2	9	6	10	0	0	0	0	0	0	0
	30	0	0	0	1	2	1	0	0	7	4	6	4	1	0	0	0	0	0
	34	0	0	0	0	1	0	0	0	5	14	2	0	0	0	0	0	0	0
	38	0	0	0	0	0	2	2	0	3	17	0	1	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	1	5	3	0	1	0	0	0	0	0	0
	46	0	0	0	1	0	0	0	0	10	3	2	2	1	0	0	0	0	0
	50	0	0	0	0	0	0	0	6	15	3	1	1	1	0	0	0	0	0
	54	0	0	0	0	0	0	0	10	17	4	4	1	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	1	4	0	5	0	0	0	0	0	0
	62	0	0	0	0	0	0	0	1	4	1	0	0	1	0	0	0	0	0
	66	0	0	0	0	0	0	0	0	3	0	1	0	1	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	5	0	1	1	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	0	2	1	2	0	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	0	1	1	11	1	0	0	0	0	0	0

TABLE C-63. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 29 28MPH
TEST 64

RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
-2	0	0	0	1	2	7	0	7	10	10	12	2	0	0	0	0	0	0
2	0	1	325	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	2	0	4	1	0	3	0	1	0	0	0	0	0
10	0	0	0	0	1	0	0	1	1	5	2	1	1	0	0	0	0	0
14	0	0	0	0	0	0	0	1	0	3	3	1	0	0	0	0	0	0
18	0	0	0	0	0	0	0	1	0	2	9	0	0	1	0	0	0	0
22	0	0	0	0	1	0	0	1	0	4	5	1	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	5	2	7	2	0	7	0	0	0	0
30	0	0	0	0	0	0	0	0	1	4	2	1	1	2	1	0	0	0
34	0	0	0	0	0	0	2	0	4	1	7	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	1	2	3	0	0	2	0	0	0	0
42	0	0	0	0	0	0	0	1	0	1	5	5	1	0	1	0	0	0
46	0	0	0	0	0	0	0	1	2	0	1	1	0	3	0	0	0	0
50	0	0	0	0	0	0	0	0	1	0	4	3	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	1	2	1	6	2	0	2	0	0	0
58	0	0	0	0	0	0	1	0	1	1	2	2	0	1	2	0	0	0
62	0	0	0	0	0	0	0	1	0	1	1	3	0	2	0	0	0	0
66	0	0	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	2	2	0	1	1	0	0	0	0
78	0	0	0	0	0	0	0	0	0	1	2	0	1	2	0	0	0	0
82	0	0	0	0	0	0	0	0	0	2	2	3	2	3	0	0	0	0
86	0	0	0	0	0	0	0	0	0	1	3	0	1	0	1	0	0	0
90	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0	2	12	12	0	2	0	0	0	0
98	0	0	0	0	0	0	0	0	2	7	19	62	20	7	1	0	0	0

TABLE C-44. TIME (SECONDS) SPENT IN PERCENT POWER-RPM INTERVALS FOR 32 KPH CYCLE

TRUCK 30 20MPH TEST 64	RPM PWR	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
	-2	0	0	0	5	12	20	10	5	6	2	0	0	0	0	0	0	0	0
	2	1	114	29	1	0	2	2	2	2	0	0	0	0	0	0	0	0	0
	6	0	0	0	1	2	0	2	3	6	0	0	2	0	0	0	0	0	0
	10	0	0	1	0	1	0	1	6	16	2	0	0	0	0	0	0	0	0
	14	0	0	0	1	1	0	2	5	19	7	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	1	5	6	6	13	1	0	0	0	0	0	0	0
	22	0	0	0	0	1	0	5	0	13	10	0	0	1	0	0	0	0	0
	26	0	0	0	1	1	0	5	15	10	2	2	1	0	0	0	0	0	0
	30	0	0	0	0	1	2	1	9	7	1	12	1	2	1	0	0	0	0
	34	0	0	0	0	0	0	1	5	13	7	15	0	1	1	0	0	0	0
	38	0	0	0	1	0	1	0	3	9	7	16	4	0	0	0	0	0	0
	42	0	0	0	0	0	0	1	0	2	3	17	0	0	1	0	0	0	0
	46	0	0	0	0	0	0	0	1	21	0	4	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	1	6	1	5	1	0	0	0	0	0	0
	54	0	0	0	0	0	0	0	0	10	15	17	2	0	0	0	0	0	0
	58	0	0	0	0	0	0	0	0	0	7	20	1	1	2	0	0	0	0
	62	0	0	0	0	0	0	0	1	3	1	6	1	2	1	0	0	0	0
	66	0	0	0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0
	74	0	0	0	0	0	0	0	0	5	1	2	2	0	0	0	0	0	0
	78	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0
	82	0	0	0	0	0	0	0	0	0	1	3	1	2	0	0	0	0	0
	86	0	0	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0
	94	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0
	98	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0

TABLE C-45. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 12 DIESEL TRUCKS, DRIVING CYCLE EMISSIONS AND FUEL RATE

Truck No.	Constant		Load		Speed		Load X Speed		Goodness of Fit		
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	r^2	Std. Dev.	Coeff. of Var.
					HC Emissions						
19	1.2750	0.7950	0.0332	0.1081	0.4314	0.2903	0.0216	0.0395	0.7170	0.2408	10.93
20	0.6067	0.1695	-0.0025	0.0071	0.0680	0.0619	0.0004	0.0026	0.5816	0.0906	12.17
21	0.4717	0.1381	0.0036	0.0058	0.0503	0.0504	-0.0005	0.0021	0.3998	0.0738	11.36
22	1.3583	0.1666	-0.0027	0.0069	0.1680*	0.0608	-0.0055	0.0025	0.8409	0.0891	6.30
23	0.5317	0.1310	0.0092	0.0055	0.2120**	0.0479	-0.0041	0.0020	0.8586	0.0701	6.76
24	0.7633	0.1495	0.0045	0.0062	0.2463**	0.0546	-0.0013	0.0023	0.9336	0.0799	5.67
25	1.1750	0.4846	0.0106	0.0202	0.2527	0.1769	-0.0053	0.0074	0.3712	0.2590	14.81
26	0.2967	0.0580	0.0041	0.0037	0.1083***	0.0212	0.0006	0.0013	0.9663	0.0309	4.77
27	0.7383	0.2261	0.0250*	0.0094	0.3350**	0.0826	-0.0105*	0.0034	0.7151	0.1209	7.81
28	1.1325	0.2506	-0.0069	0.0192	0.1577	0.0915	0.0007	0.0070	0.7714	0.1248	8.53
29	0.7408	0.6309	0.0323	0.0674	0.1535	0.2304	-0.0110	0.0246	0.2004	0.1502	12.86
30	0.4876	0.0511	0.0055	0.0039	0.1368***	0.0187	0.0003	0.0014	0.9830	0.0255	2.82
					CO Emissions						
19	3.0323	1.2492	-0.2134	0.1699	-0.2655	0.4561	0.1196	0.0620	0.8404	0.3785	12.69
20	0.7333	1.1319	0.0180	0.0471	0.2000	0.4133	0.0153	0.0172	0.7267	0.6051	24.36
21	1.8333	1.1562	0.0225	0.0482	0.7300	0.4222	0.0414*	0.1759	0.9505	0.6180	9.57
22	3.2834	1.3537	0.0945	0.0564	0.9200	0.4943	0.0558*	0.0206	0.9683	0.7236	6.71
23	4.033	1.4168	-0.0832	0.0590	-1.0032	0.5173	0.1399***	0.0215	0.9723	0.7573	10.17
24	3.2500	2.2807	-0.1080	0.0950	-1.4466	0.8328	0.2133***	0.0347	0.9710	1.2191	13.42
25	2.8000	1.9126	0.0067	0.0800	0.6134	0.6984	0.0337	0.0291	0.8176	1.0224	16.08
26	0.8000	1.7122	-0.0792	0.1092	-0.3201	0.6252	0.1633**	0.0399	0.9482	0.9152	19.17
27	1.9499	1.6258	-0.0787	0.0677	-1.3299	0.5937	0.2119***	0.0247	0.9861	0.8691	10.05
28	4.9536	4.5466	-0.2003	0.3475	-1.3924	1.6602	0.3516*	0.1269	0.8738	2.2639	23.14
29	0.4905	1.8960	0.1438	0.2026	0.4344	0.6923	-0.0312	0.0740	0.2304	0.4513	20.67
30	0.0090	1.6532	0.1013	0.1263	-0.1431	0.6037	0.0452	0.0461	0.7327	0.8232	36.19

Significance:
* = 0.05
** = 0.01
*** = 0.001

TABLE C-45 (cont'd). COEFFICIENTS FROM MULTIPLE LINEAR REGRESSIONS OF EMISSIONS DATA FROM 12 DIESEL TRUCKS, DRIVING CYCLE EMISSIONS AND FUEL RATE

Truck No.	Constant		Load		Speed		Load X Speed		Goodness of Fit		
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	r^2	Std. Dev.	Coeff. of Var.
					NO$_x$ Emissions						
19	0.8908	0.8606	-0.0249	0.1170	0.1912	0.3142	0.1001*	0.0427	0.9634	0.2607	8.73
20	1.2117	0.8128	-0.0142	0.0339	0.5724	0.2968	0.0774***	0.0124	0.9874	0.4345	6.56
21	1.3133	1.4704	-0.0160	0.0612	0.7947	0.5369	0.1025*	0.0224	0.9772	0.7860	9.10
22	0.6634	0.6387	0.0616*	0.0266	1.8204***	0.2332	0.0288*	0.0097	0.9916	0.3414	4.17
23	2.1684	1.2078	0.1075	0.0503	4.0861***	0.4410	0.0674**	0.0184	0.9940	0.6456	3.49
24	2.1117	0.6634	0.0166	0.0276	0.6911	0.2422	0.1321	0.0101	0.9970	0.3546	3.07
25	0.1667	0.9414	0.0263	0.0392	0.4061	0.3437	0.0952***	0.0143	0.9886	0.5032	7.13
26	1.1367	0.8689	-0.0262	0.0554	1.0263*	0.3173	0.0824**	0.0202	0.9815	0.4644	7.36
27	0.3600	1.1575	0.0324	0.0482	1.0794*	0.4227	0.0588**	0.0176	0.9754	0.6187	8.78
28	1.9468	0.8438	-0.0319	0.0645	0.0749	0.3081	0.0829**	0.0235	0.9517	0.4202	9.82
29	-0.4182	0.8891	0.1010	0.0950	0.9642	0.3247	0.0198	0.0347	0.9828	0.2116	6.26
30	1.1247	1.0626	-0.0246	0.0812	0.6669	0.3880	0.0744	0.0297	0.9534	0.5291	11.09
					Fuel Consumption						
19	35.8855	13.7240	-0.8304	4.3146	13.9302	11.5840	2.2070	1.5755	0.9503	9.6111	9.21
20	55.3783	14.5284	0.1381	0.6052	29.8935***	5.3050	1.1735***	0.2210	0.9918	7.7659	3.91
21	50.6468	16.4018	0.4400	0.6832	33.8345***	5.9891	1.2273***	0.2495	0.9913	8.7674	4.11
22	18.5204	13.0935	1.4069*	0.5454	37.5379***	4.7811	0.6167**	0.1992	0.9920	6.9990	3.93
23	56.7214	8.7713	0.0358	0.3654	32.5998***	3.2029	0.9746***	0.1334	0.9966	4.6886	2.43
24	74.8646	18.9050	-0.2121	0.7875	34.4724**	6.9031	1.7529***	0.2875	0.9920	10.1054	3.98
25	33.9807	18.4740	1.6300	0.7695	26.9390**	6.7557	1.2252**	0.2810	0.9886	9.8751	4.80
26	29.5167	8.8933	0.1054	0.5672	28.6143***	3.2474	1.0566***	0.2071	0.9945	4.7536	3.37
27	49.7762	14.9443	-0.0859	0.6225	19.6429**	5.4569	1.6263***	0.2273	0.9923	7.9883	4.26
28	74.6342	20.8816	-1.0716	1.5958	6.8974	7.6249	2.4144**	0.5827	0.9701	10.3977	6.81
29	-0.1134	20.3744	2.5783	2.1775	33.4560**	7.4397	0.0408	0.7951	0.9893	4.8492	4.48
30	31.9625	10.9736	-0.1628	0.8386	20.4547***	4.0069	1.1662**	0.3062	0.9885	5.4641	4.68

Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE C-46. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 12 DIESEL TRUCKS, SINUSOIDAL CYCLE EMISSIONS AND FUEL RATE

	Constant		Load		Speed		Load X Speed		Goodness of Fit		
Truck No.	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	r^2	Std. Dev.	Coeff. of Var.
HC Emissions											
19	3.5499	3.8248	-0.3328	0.5202	0.1598	0.6151	0.0439	0.0837	0.7301	0.6455	16.10
20	0.4439	0.8164	0.0513	0.0340	0.0375	0.1313	-0.0058	0.0055	0.6126	0.2431	23.63
21	0.3634	0.4091	0.0541*	0.0170	0.0200	0.0658	-0.0067	0.0027	0.8952	0.1218	15.48
22	4.8422	1.0720	-0.0644	0.0447	-0.2283	0.1724	0.0037	0.0072	0.7844	0.3192	12.59
23	0.2906	0.4669	0.0133	0.0194	0.1275	0.0751	0.0010	0.0031	0.8945	0.1390	9.36
24	1.4161	0.9314	-0.0184	0.0388	0.1075	0.1498	0.0040	0.0062	0.7210	0.2773	12.66
25	1.8945	1.1316	0.1238*	0.0471	-0.0367	0.1820	-0.0147	0.0076	0.8888	0.3370	13.69
26	-0.0639	0.3627	0.0379	0.0231	0.0992	0.0583	-0.0014	0.0037	0.8804	0.1080	11.24
27	3.7350	2.8450	0.0032	0.1185	-0.0875	0.4575	-0.0028	0.0191	0.1620	0.8472	29.15
28	1.6525	0.5012	0.0421	0.0383	-0.0165	0.0806	-0.0029	0.0062	0.6570	0.1390	7.50
29	5.3517	1.0876	-0.5072**	0.1162	-0.3101	0.1749	0.0613*	0.0187	0.9552	0.1442	6.55
30	0.7568	0.3263	-0.0293	0.0249	0.1300	0.0525	0.0035	0.0040	0.9476	0.0905	6.30
CO Emissions											
19	0.3834	5.3523	0.0735	0.7279	0.7053	0.8607	-0.0193	0.1171	0.6557	0.9033	20.95
20	-1.1944	3.3543	0.2819	0.1397	0.3750	0.5394	-0.0337	0.0225	0.6739	0.9989	35.39
21	-5.1997	5.0485	0.6141*	0.2103	0.8833	0.8119	-0.0596	0.0338	0.8425	1.5034	25.92
22	8.3446	2.7379	0.0907	0.1140	-1.5166*	0.4403	0.0506*	0.0183	0.9739	0.8153	10.18
23	-17.2995	17.5701	1.3662	0.7319	2.5499	2.8256	-0.1665	0.1177	0.5768	5.2320	84.84
24	-17.4996	20.2791	1.3737	0.8447	1.9666	3.2612	-0.1327	0.1358	0.6259	6.0388	84.66
25	-0.0332	3.1577	0.2347	0.1315	1.0000	0.5078	-0.0304	0.0212	0.5914	0.9403	13.18
26	-11.3564	9.2369	1.2803	0.5892	1.2167	1.4855	-0.1257	0.0947	0.7434	2.7505	76.88
27	-6.5331	12.0747	0.6681	0.5030	0.5000	1.9418	-0.0281	0.0809	0.7429	3.5956	47.52
28	6.1416	7.3735	0.1014	0.5635	-0.9044	1.1858	0.0841	0.0906	0.7798	2.0456	25.15
29	5.8648	2.4887	-0.5160	0.2660	-0.2287	0.4002	0.0709	0.0428	0.8985	0.3299	9.027
30	-4.2198	1.7496	0.6349**	0.1337	0.7919*	0.2814	-0.0783*	0.0215	0.8843	0.4853	18.99

Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE C-46 (cont'd). COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 12 DIESEL TRUCKS, SINUSOIDAL CYCLE EMISSIONS AND FUEL RATE

Truck No.	Constant		Load		Speed		Load X Speed		Goodness of Fit		
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	r^2	Std. Dev.	Coeff. Of Var.
					NO_x Emissions						
19	-2.5330	4.2808	0.5564	0.5822	1.1660	0.6884	-0.0644	0.0936	0.8304	0.7225	12.71
20	-1.8181	4.0637	0.2878	0.1693	0.7958	0.6535	0.0074	0.0272	0.9343	1.2101	11.70
21	-4.2221	3.5442	0.3373	0.1476	2.1467*	0.5700	-0.0144	0.0237	0.9580	1.0554	7.41
22	-3.3380	9.5330	-0.1492	0.3971	1.9167	1.5331	0.0751	0.0639	0.9058	2.8388	19.10
23	-13.5704	13.2906	0.5903	0.5536	5.9016*	2.1373	0.0069	0.0890	0.9376	3.9577	11.03
24	-2.1235	5.6916	0.5655	0.2371	1.2292	0.9153	0.0030	0.0381	0.9533	1.6949	9.30
25	-2.0587	2.8652	0.2004	0.1193	0.7150	0.4608	0.0288	0.0192	0.9761	0.8532	8.11
26	-5.2892	2.7335	0.6602*	0.1743	1.5934	0.4396	-0.0440	0.0280	0.9566	0.8140	8.13
27	-0.8916	1.3930	0.1140	0.0580	0.7109*	0.2240	0.0489**	0.0093	0.9958	0.4148	3.34
28	4.4948	1.5742	-0.2278	0.1203	-0.0816	0.2532	0.0684*	0.0193	0.9594	0.4367	6.99
29	-0.8144	3.5738	0.1661	0.3819	0.9431	0.5747	0.0013	0.0614	0.9526	0.4739	7.35
30	-0.9412	2.2971	0.3111	0.1755	1.2398*	0.3694	-0.0234	0.0282	0.9316	0.6372	7.42
					Fuel Consumption						
19	-28.9901	192.9404	14.8584	26.2408	27.3128	13.0281	-0.9508	4.2199	0.6935	32.5633	16.23
20	32.6653	86.5504	4.9192	3.6052	27.2406	13.9188	0.0510	0.5798	0.9225	25.7732	8.25
21	57.9424	119.2963	2.1632	4.9692	38.1284	19.1849	0.1049	0.7991	0.8772	35.5244	10.19
22	126.0318	70.6151	3.5578	2.9414	8.0604	11.3561	0.2197	0.4730	0.9077	21.0280	7.44
23	548.1885	304.8754	-12.9523	12.6993	-78.0444	49.0291	3.7326	2.0423	0.6956	90.7866	31.33
24	62.6644	59.9040	5.6191	2.4952	34.0291*	9.6336	0.1630	0.4013	0.9766	17.8384	4.31
25	45.4277	98.7553	2.0271	4.1136	28.0547	15.8815	0.4628	0.6615	0.9243	29.4076	9.18
26	-66.9217	96.7745	10.7437	6.1725	37.6263	15.5630	-0.7802	0.9926	0.8737	28.8165	11.68
27	-24.9133	80.0133	2.2231	3.3329	32.8621	12.8675	0.7031	0.5360	0.9688	23.8266	7.55
28	167.1961	51.5582	-4.6947	3.9402	-0.6709	8.2914	1.4953	0.6336	0.9221	14.3018	6.64
29	1.9065	120.0946	4.5182	12.8350	24.6736	19.3132	0.1150	2.0641	0.9287	15.9233	8.04
30	-2.8648	75.5056	3.9169	5.7703	27.4405	12.1426	-0.1463	0.9280	0.8890	20.9447	10.53

Significance: * = 0.005
** = 0.01
*** = 0.001

TABLE C-47. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 12 DIESEL TRUCKS, STEADY-STATE EMISSIONS AND FUEL RATE

Truck No.	Constant		Load		Speed		Load X Speed		Goodness of Fit		
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	r^2	Std. Dev.	Coeff. of Var.
					HC Emissions						
19	1.6838	1.3942	0.0612	0.1896	0.2816	0.2489	0.0068	0.0339	0.6612	0.9137	25.60
20	0.7495	0.1443	-0.0084	0.0060	0.2677	0.0258	0.0009	0.0011	0.5605	0.1669	21.70
21	0.4236	0.0789	-0.0015	0.0033	0.0303*	0.0141	-0.0007	0.0006	0.4165	0.0912	19.89
22	2.1959	1.0118	0.0033	0.0421	0.1228	0.1806	-0.0038	0.0075	0.0396	1.1699	48.09
23	0.9313	0.2407	-0.0012	0.0100	0.0963*	0.0430	0.0020	0.0018	0.7955	0.2784	18.31
24	1.8019	0.4041	-0.0173	0.0168	0.0012	0.0721	0.0056	0.0030	0.5587	0.4673	23.74
25	1.5143	0.4719	-0.0003	0.0197	0.0388	0.0842	-0.0013	0.0035	0.0228	0.5456	35.11
26	0.3736	0.1764	0.0045	0.0113	0.0755*	0.0315	0.0019	0.0020	0.7971	0.2040	22.97
27	2.1602	1.1759	0.0020	0.0490	0.1413	0.2099	-0.0058	0.0087	0.0500	1.3597	60.24
28	0.8360	0.4335	0.0241	0.0331	0.1601	0.0773	-0.0081	0.0059	0.2655	0.4669	33.34
29	1.4070	1.4456	0.0563	0.1545	0.2573	0.2581	-0.0205	0.0276	0.1353	0.7443	33.46
30	0.9976	0.2628	-0.0139	0.0201	0.0851	0.0469	0.0044	0.0036	0.7840	0.2831	19.72
					CO Emissions						
19	2.1002	1.6328	0.0578	0.2221	0.2781	0.2915	-0.0074	0.0396	0.3951	1.0701	30.57
20	1.3268	0.4069	-0.0295	0.0169	0.1215	0.7265	0.0047	0.0030	0.7795	0.4705	28.37
21	2.8508	2.1385	-0.1121	0.0891	0.8364	0.3818	0.3821*	0.0159	0.7082	2.4728	55.67
22	1.1775	3.6799	-0.0512	0.1533	0.9937	0.6570	0.0120	0.0274	0.5645	4.2551	76.67
23	5.1565	2.6495	-0.1385	0.1104	-0.8520	0.4730	0.0536*	0.0197	0.3936	3.0636	85.89
24	10.4922	6.0403	-0.4236	0.2516	-1.7601	1.0784	0.1237*	0.0449	0.4123	6.9843	129.24
25	3.1482	1.0102	-0.0536	0.0421	0.2185	0.1804	0.0223**	0.0075	0.8584	1.1681	23.00
26	4.5427	4.0573	-0.3422	0.2588	-1.0346	0.7243	0.1286*	0.0462	0.4852	4.6912	145.84
27	7.6012	6.8723	-0.4013	0.2863	-1.8783	1.2269	0.1515**	0.0511	0.5150	7.9464	152.94
28	9.5082	8.4473	-0.9244	0.6456	-2.5011	1.5081	0.3972**	0.1153	0.6414	9.0987	106.68
29	3.7214	2.9559	0.0003	0.3159	0.4251	0.5277	-0.0399	0.0563	0.0781	1.5218	38.29
30	3.5279	2.4498	-0.2946	0.1872	-0.8315	0.4374	0.1098**	0.0334	0.5494	2.6387	122.02

Significance: * = 0.05
** = 0.01
*** = 0.001

TABLE C-47 (cont'd). COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION OF EMISSIONS DATA FROM 12 DIESEL TRUCKS, STEADY-STATE EMISSIONS AND FUEL RATE

Truck	Constant		Load		Speed		Load X Speed		Goodness of Fit		
No.	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	r^2	Std. Dev.	Coeff. of Var.
					NO$_x$ Emissions						
19	1.5372	1.5822	-0.1551	0.2152	0.1653	0.2825	0.1055*	0.0384	0.9247	1.0369	23.24
20	0.1855	5.1046	-0.1800	0.2126	1.0064	0.9113	0.0821*	0.0380	0.7875	5.9024	68.84
21	1.8449	5.0652	-0.2175	0.2110	1.0723	0.9043	0.0952	0.0377	0.8272	5.8568	53.43
22	1.5944	2.8707	-0.1218	0.1196	1.5536**	0.5125	0.0593*	0.0213	0.9203	3.3194	29.00
23	-0.7741	6.2154	-0.1218	0.2589	5.1874***	1.1096	0.0682	0.0462	0.9283	7.1868	27.80
24	5.2835	5.8784	-0.3227	0.2449	-0.1016	1.0495	0.1461	0.0437	0.7967	6.7972	57.23
25	2.8468	5.1384	-0.2800	0.2140	-0.1042	0.9173	0.1197**	0.0382	0.7713	5.9414	76.14
26	0.2390	5.0665	-0.2429	0.3232	1.1441	0.9045	0.1012	0.0577	0.7575	5.8581	71.92
27	-0.1654	3.5484	-0.1068	0.1478	1.1294	0.6335	0.0588	0.0264	0.8475	4.1030	50.52
28	2.5941	1.4479	-0.1723	0.1107	0.0511	0.2585	0.0854***	0.0198	0.8962	1.5595	29.51
29	0.1512	1.9182	-0.0350	0.2050	0.7126	0.3424	0.0398	0.0366	0.9464	0.9876	21.70
30	0.4578	2.8586	-0.1602	0.2185	0.9192	0.5103	0.0682	0.0390	0.8326	3.0790	49.87
					Fuel Consumption						
19	36.7757	33.8315	-1.6962	4.6012	19.0803**	6.0399	1.1047	0.8215	0.9564	22.1715	15.53
20	58.5992	41.1359	-1.7047	1.7135	31.2964***	7.3439	0.9873**	0.3059	0.9505	47.5651	18.75
21	90.3184	37.6141	-1.5927	1.5668	31.8222***	6.7152	0.8862**	0.2797	0.9553	43.4929	15.52
22	35.8909	48.4329	-1.1961	2.0174	34.7257***	8.6467	0.6393	0.3602	0.9197	56.0025	25.07
23	60.8678	36.5613	-1.0930	1.5229	33.5607***	6.5273	0.7763*	0.2719	0.9564	42.2754	16.33
24	164.7096	59.3689	-3.1436	2.4730	23.0442*	10.5990	1.4840*	0.4415	0.9136	68.6476	20.19
25	98.1502	40.3234	-2.4905	1.6796	19.5758*	7.1989	1.2125***	0.2999	0.9405	46.6255	18.93
26	43.4219	42.6543	-2.3766	2.7206	25.8755**	7.6150	1.1597	0.4857	0.9195	49.3185	25.19
27	92.6861	55.0088	-2.4634	2.2913	21.1065*	9.8206	1.2427**	0.4091	0.9029	63.6061	25.33
28	98.9432	37.2420	-3.6240	2.8461	9.3716	6.6488	1.7221**	0.5081	0.9028	40.1139	21.36
29	40.0312	48.6381	-2.2304	5.1982	17.6295	8.6833	1.4399	0.9280	0.9576	25.0412	16.19
30	53.6404	35.8264	-2.7768	2.7379	18.8009	6.3960	1.3160*	0.4888	0.9261	38.5891	22.38

Significance: * = 0.005
** = 0.01
*** = 0.001

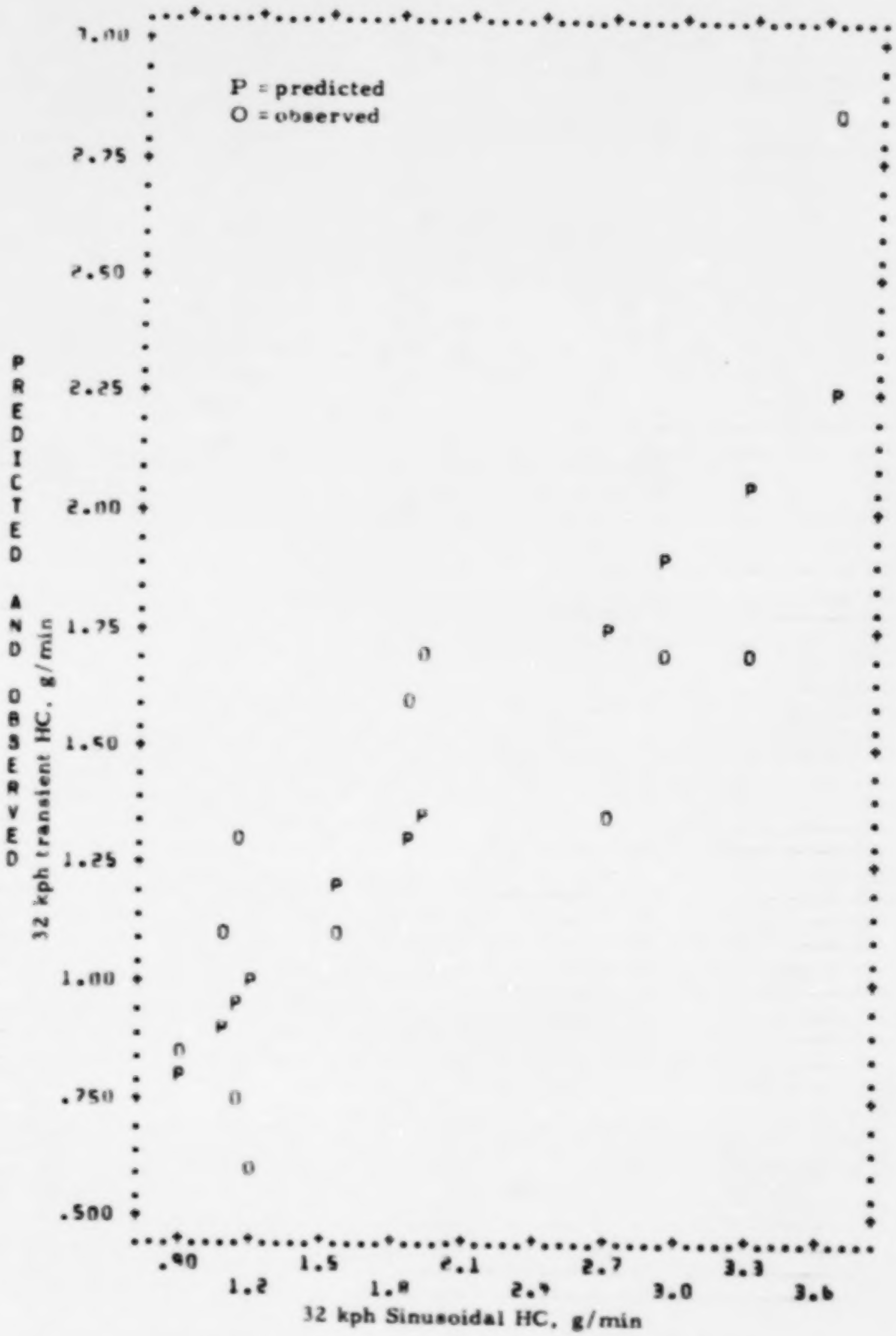


FIGURE C-1. 32 kph TRANSIENT HC EMISSIONS VERSUS 32 kph SINUSOIDAL HC EMISSIONS

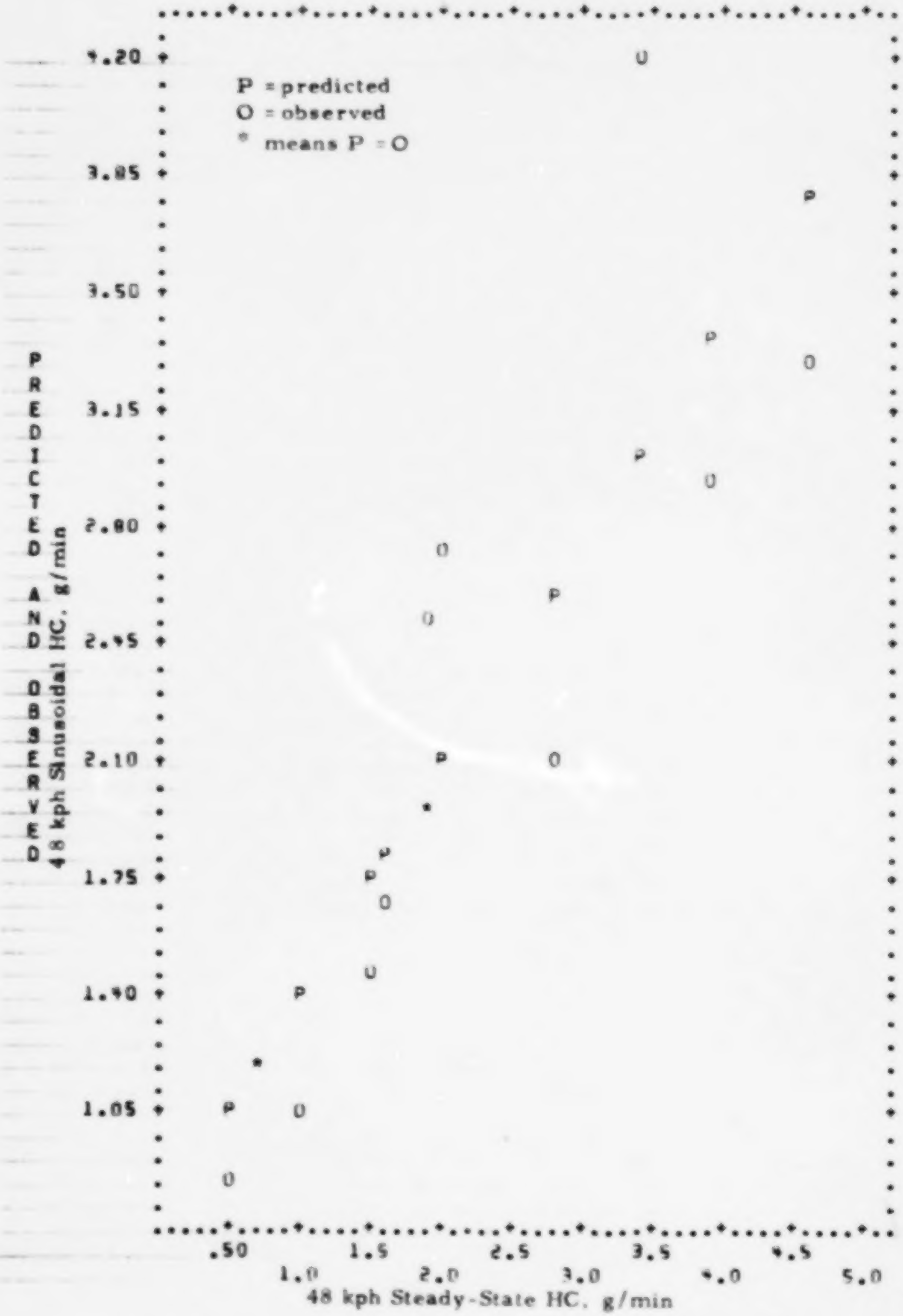


FIGURE C-2. 48 kph SINUSOIDAL HC EMISSIONS VERSUS 48 kph STEADY-STATE HC EMISSIONS

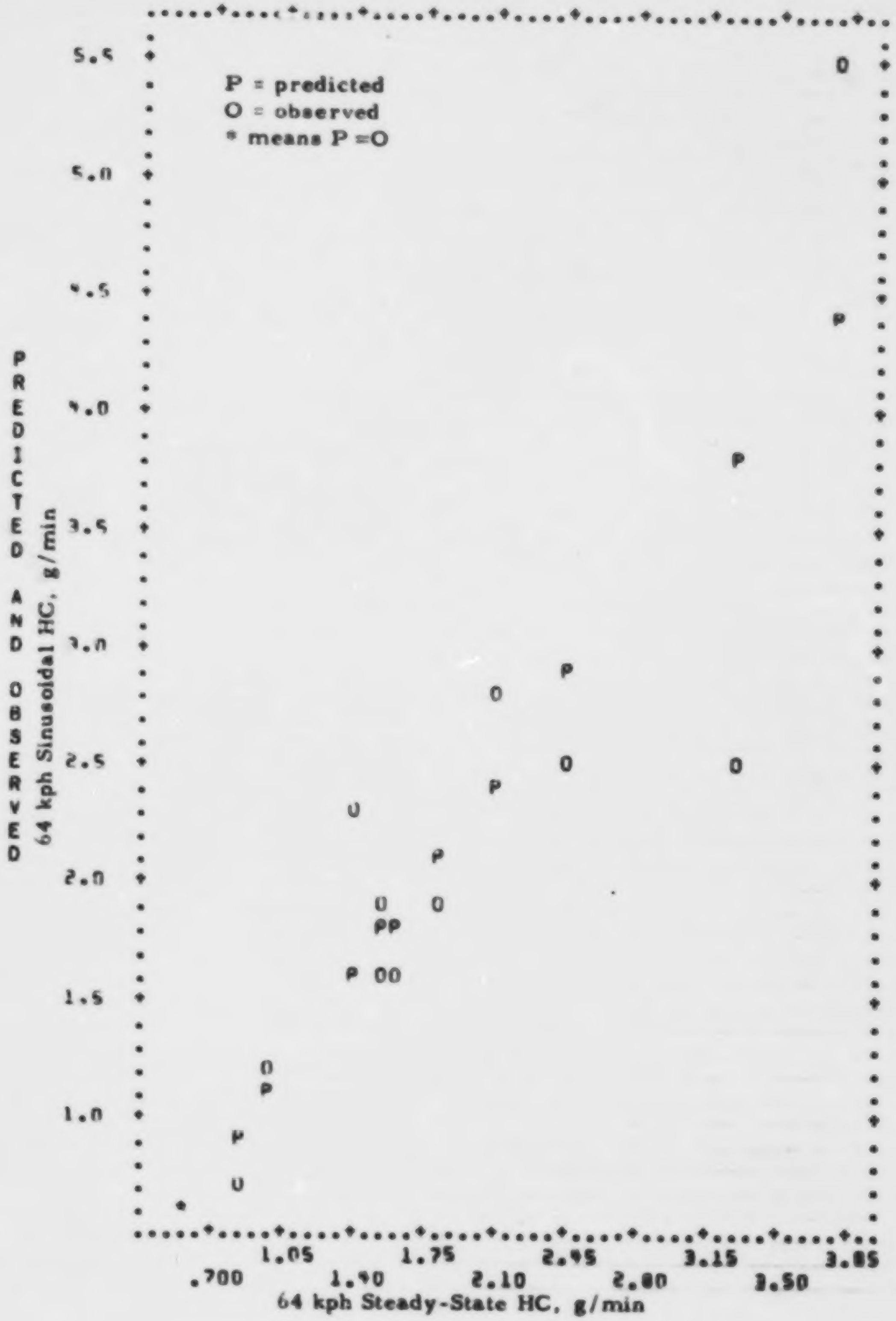


FIGURE C-3. 64 kph SINUSOIDAL HC EMISSIONS VERSUS 64 kph STEADY-STATE HC EMISSIONS

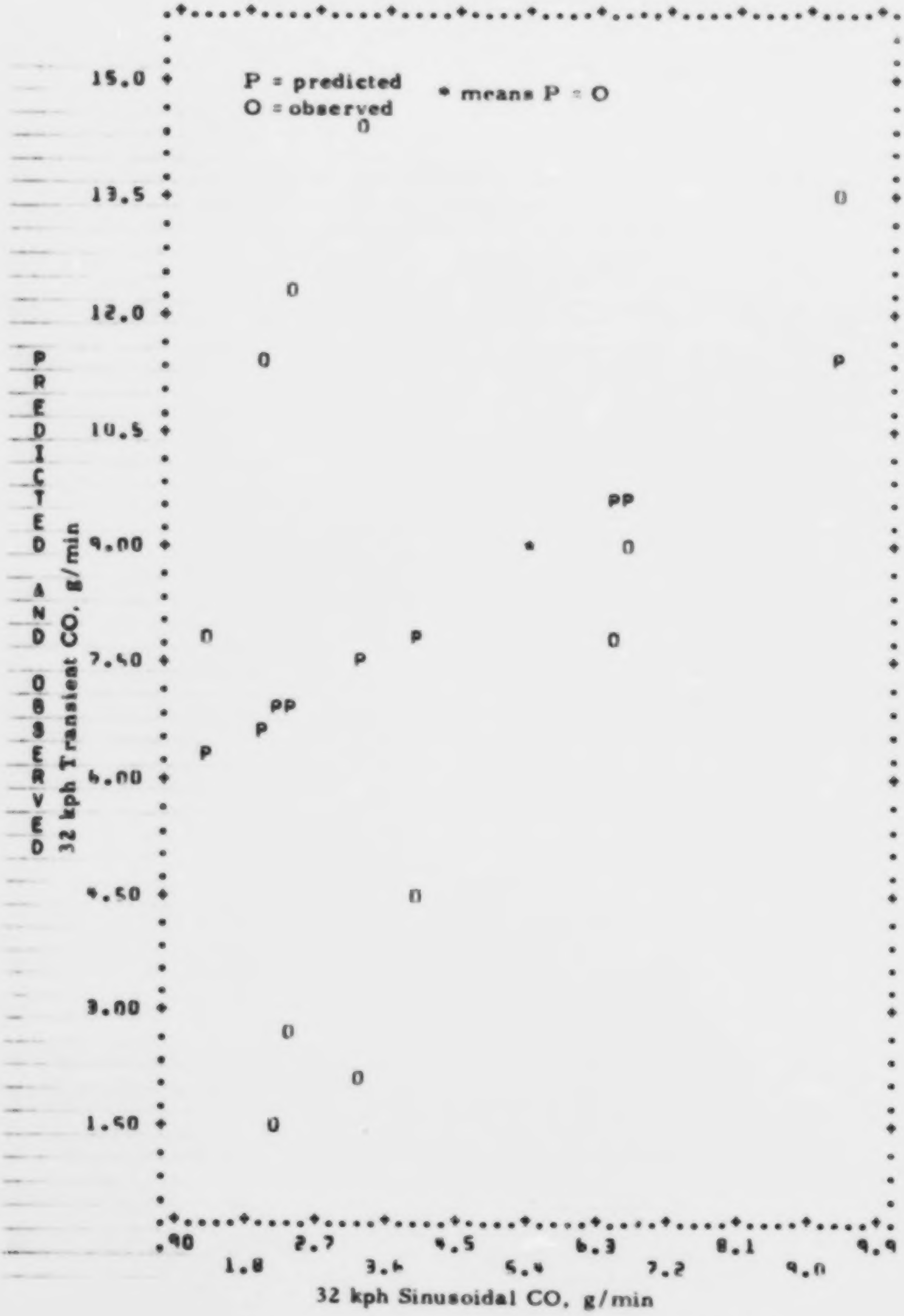


FIGURE C-4. 32 kph TRANSIENT CO EMISSIONS VERSUS 32 kph SINUSOIDAL CO EMISSIONS

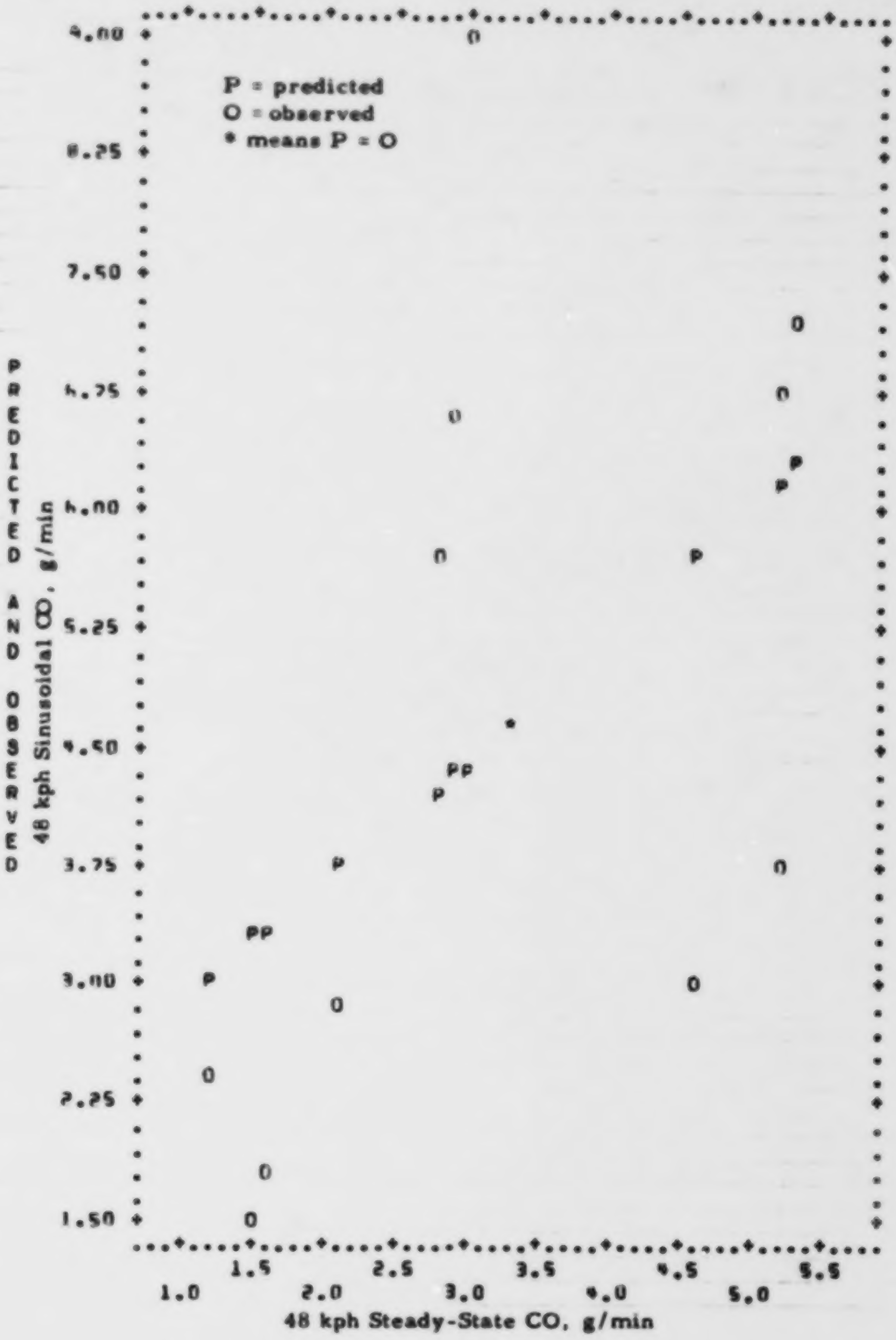


FIGURE C-5. 48 kph SINUSOIDAL CO EMISSIONS VERSUS 48 kph STEADY-STATE CO EMISSIONS

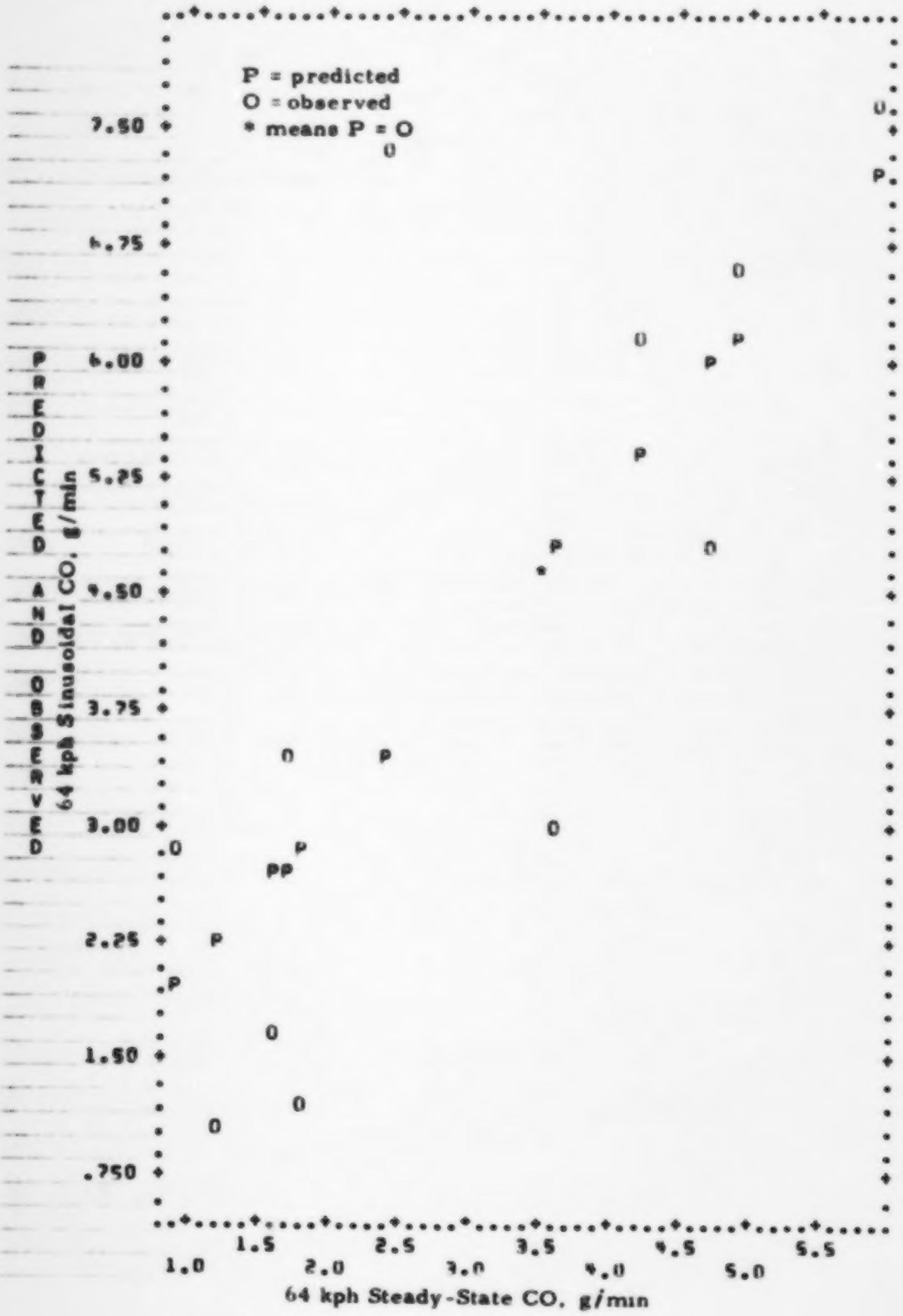


FIGURE C-6. 64 kph SINUSOIDAL CO EMISSIONS VERSUS 64 kph STEADY-STATE CO EMISSIONS

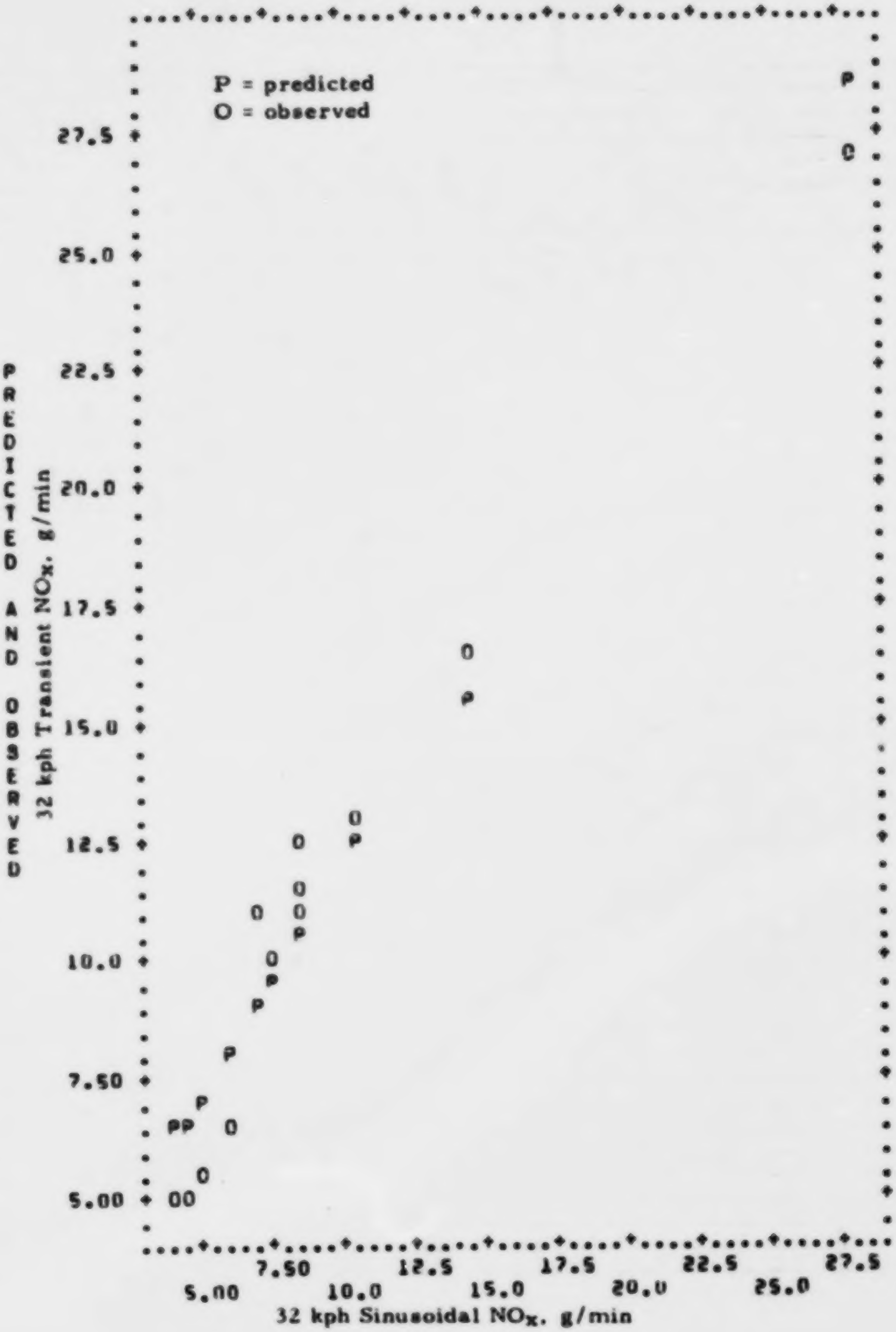


FIGURE C-7. 32 kph TRANSIENT NO_x EMISSIONS VERSUS 32 kph SINUSOIDAL NO_x EMISSIONS

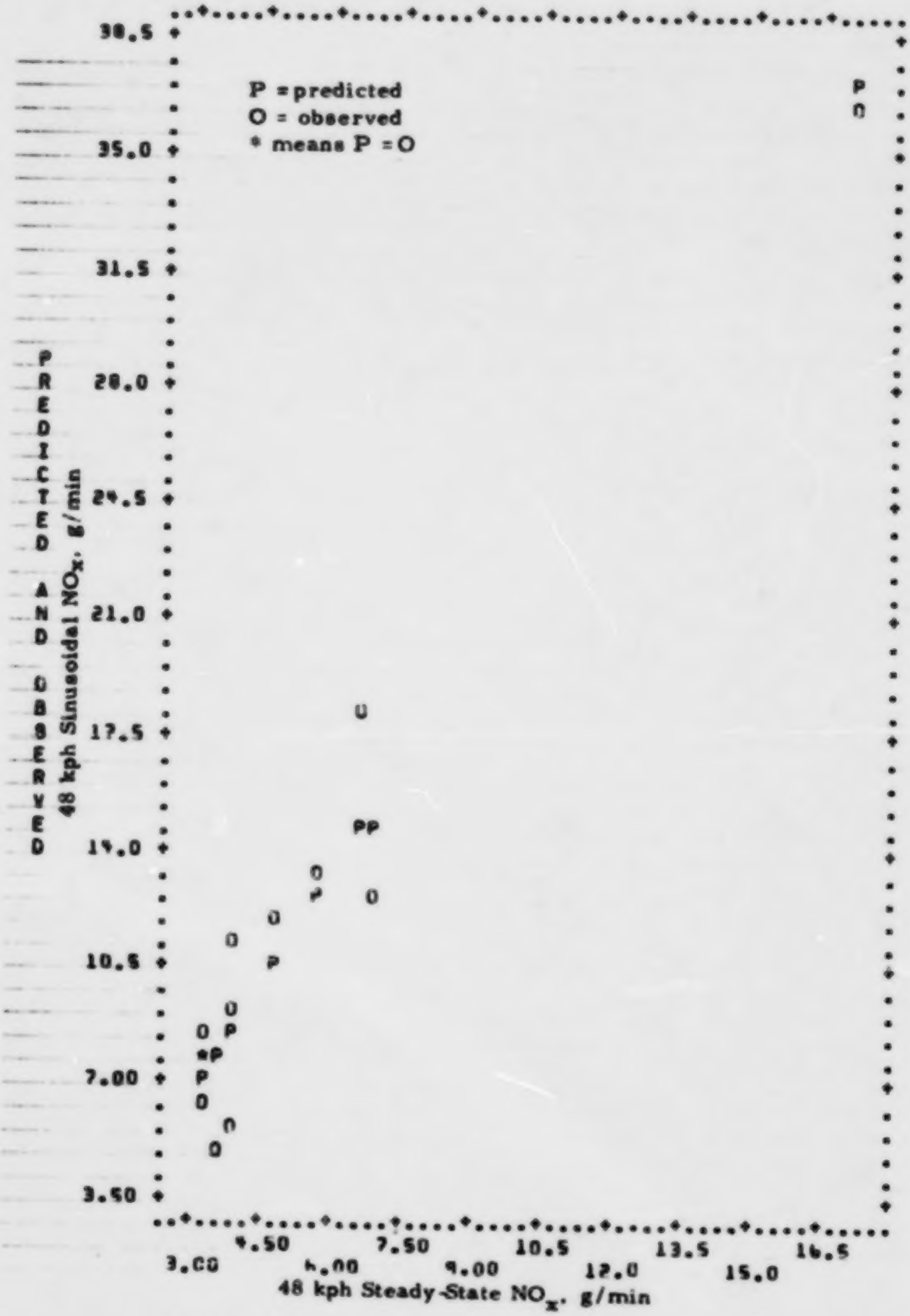


FIGURE C-8. 48 kph SINUSOIDAL NO$_x$ EMISSIONS VERSUS 48 kph STEADY-STATE NO$_x$ EMISSIONS

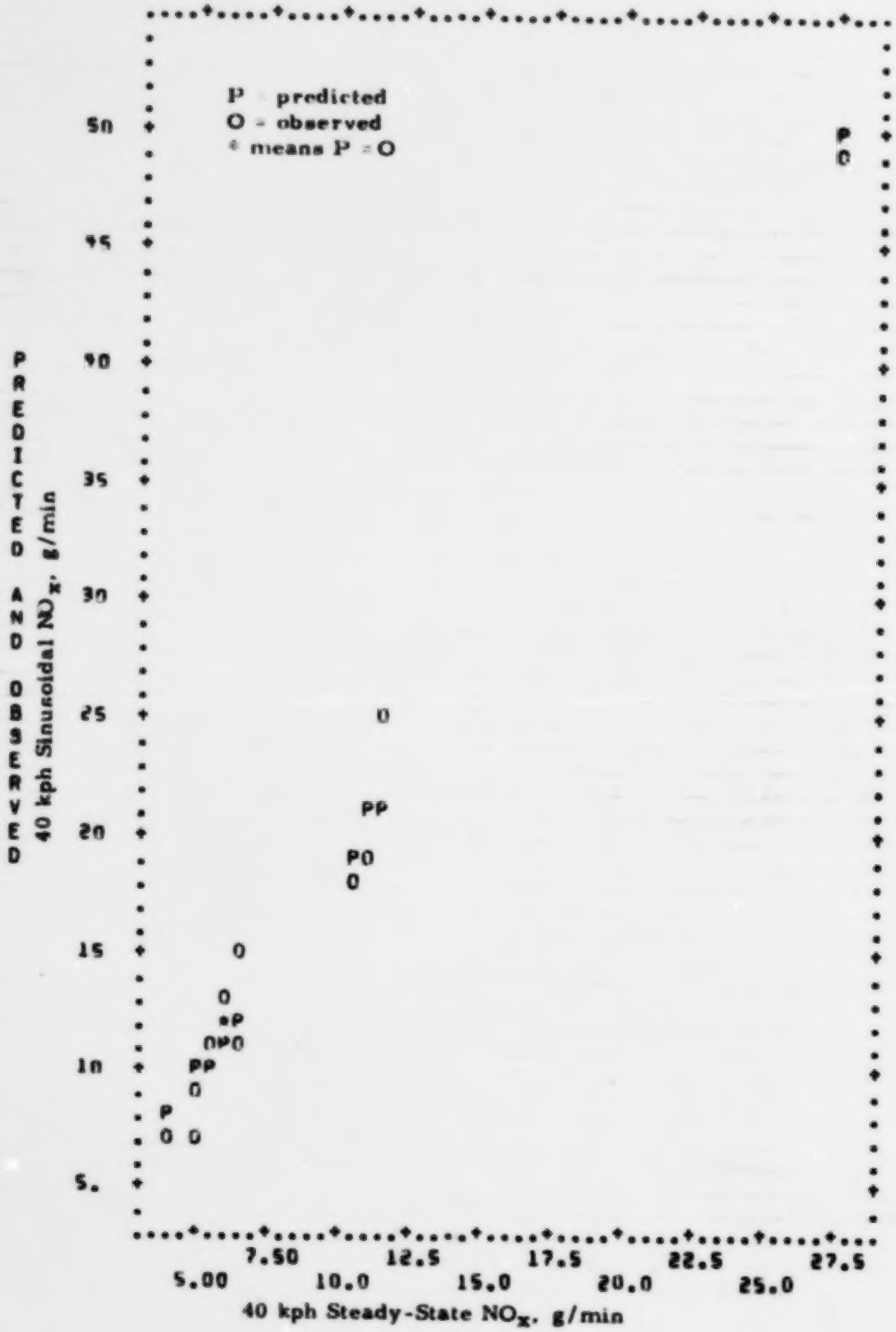


FIGURE C-9. 40 kph SINUSOIDAL NO_x EMISSIONS VERSUS 40 kph STEADY-STATE NO_x EMISSIONS

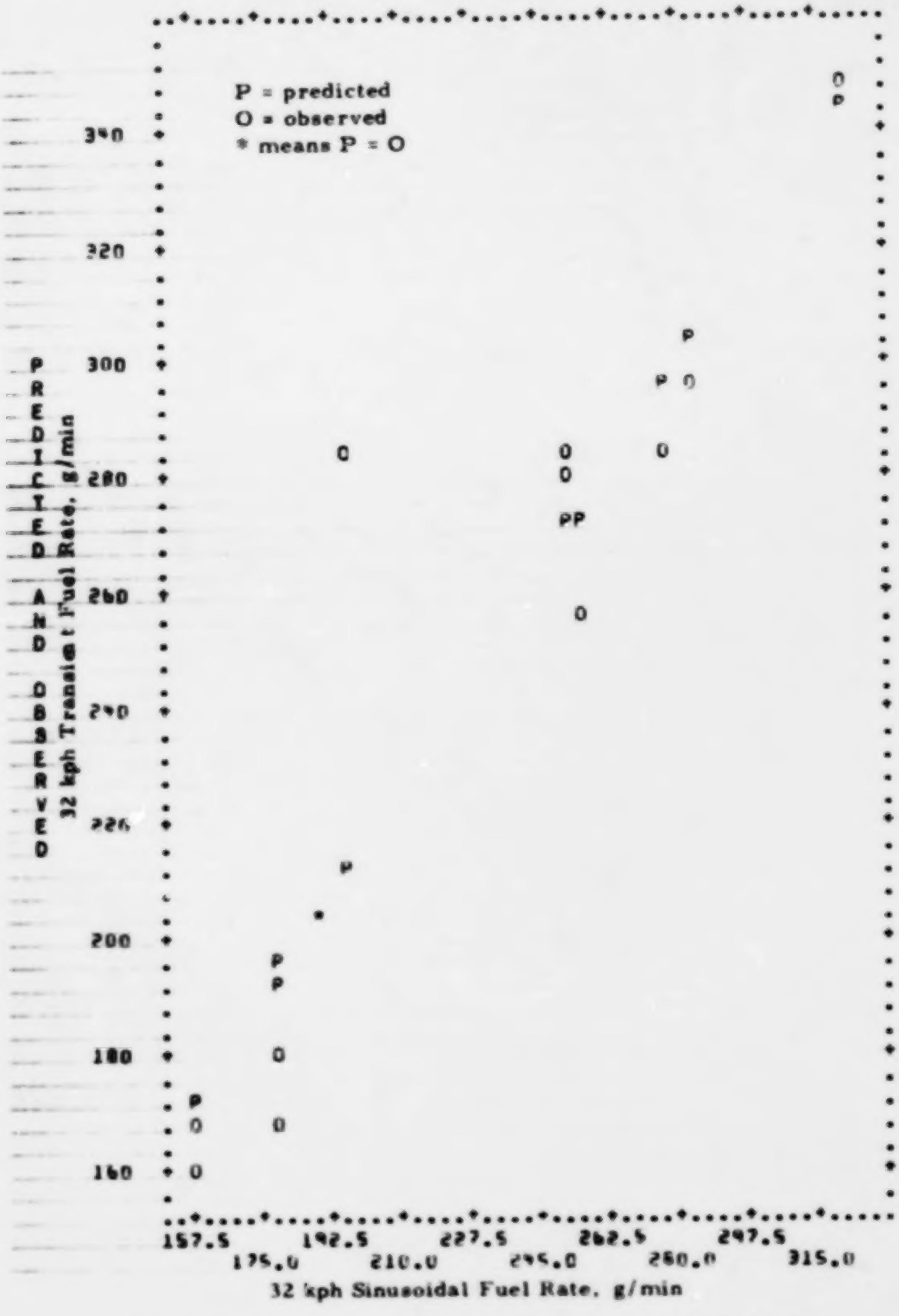


FIGURE C-10. 32 kph TRANSIENT FUEL RATE EMISSIONS VERSUS 32 kph SINUSOIDAL FUEL RATE EMISSIONS

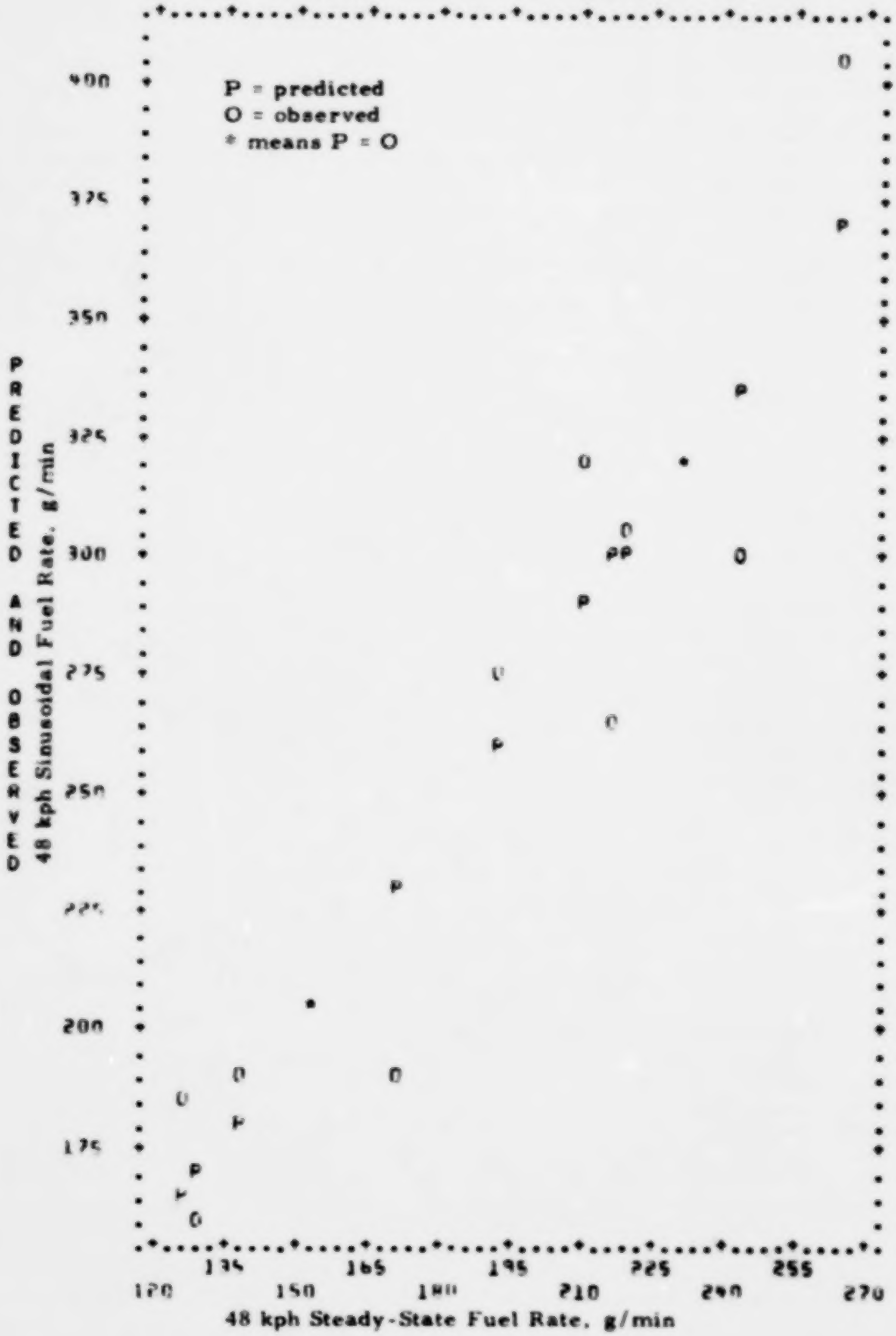


FIGURE C-11. 48 kph SINUSOIDAL FUEL RATE EMISSIONS VERSUS 48 kph STEADY-STATE FUEL RATE EMISSIONS

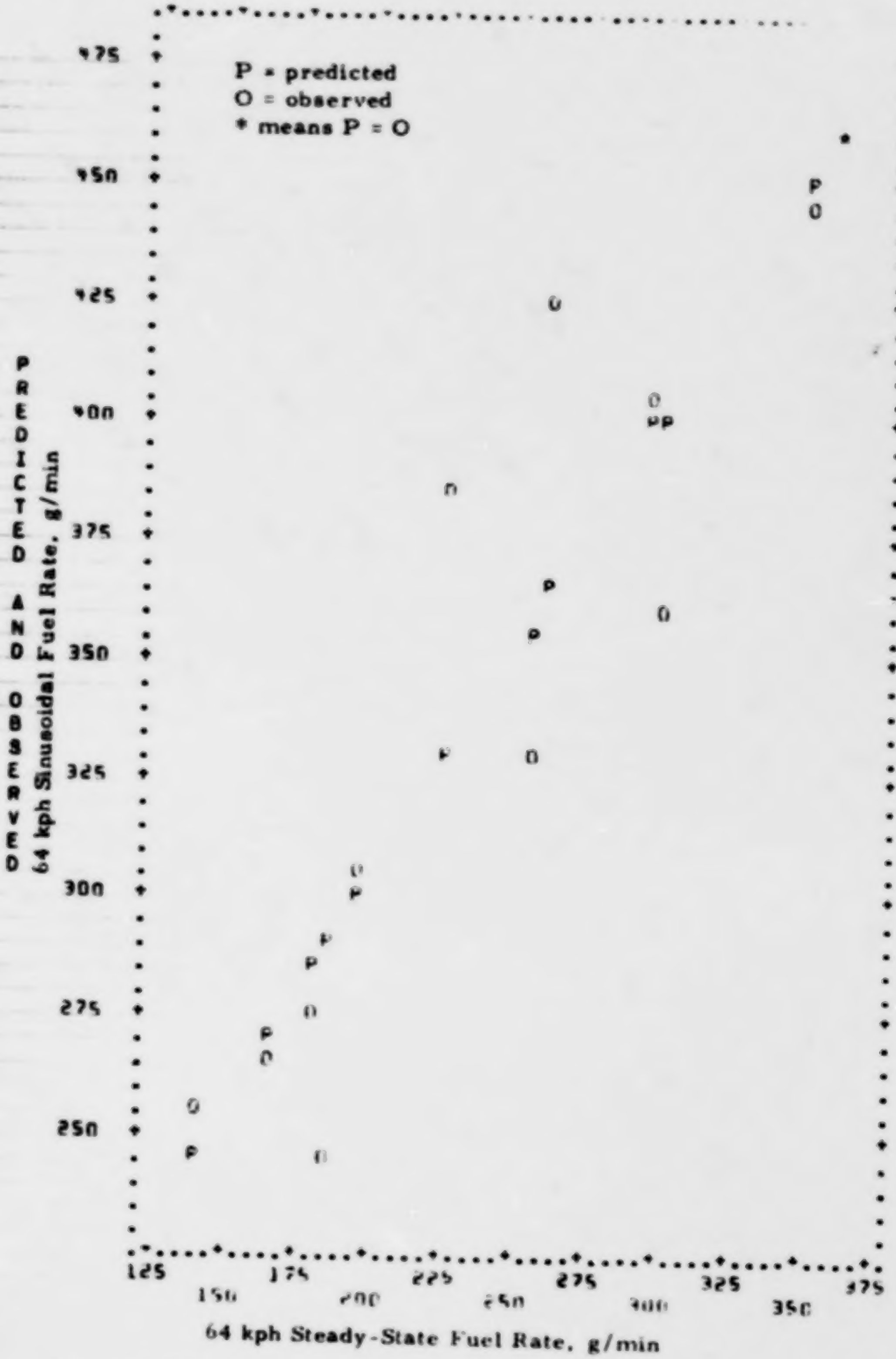


FIGURE C-12. 64 kph SINUSOIDAL FUEL RATE EMISSIONS VERSUS 64 kph STEADY-STATE FUEL RATE EMISSIONS

APPENDIX D

DATA IN SUPPORT OF GASOLINE TRUCK WEIGHTING FACTOR ANALYSIS

TABLE D-1. PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 61 TRUCKS FROM THE CAPE-21 STUDY

(ALL TRUCKS FROM NEW YORK AND LOS ANGELES)

		9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES					
TRUCK	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
02NY	40.54	0.00	0.00	10.19	1.82	4.32	56.87
03NY	34.47	12.04	1.94	2.81	2.40	3.57	57.23
04NY	23.38	18.69	1.36	1.29	.90	2.62	48.24
05NY	22.11	15.66	3.60	3.08	2.24	9.43	56.12
06NY	52.42	3.50	1.74	1.66	1.94	5.04	66.30
07NY	13.47	6.51	2.83	2.85	2.47	9.52	37.65
08NY	15.38	13.71	3.35	3.71	3.37	5.69	45.21
09NY	23.87	13.38	2.38	2.40	2.82	2.68	47.53
11NY	19.89	6.04	5.84	4.60	3.57	4.70	44.64
12NY	25.55	9.22	2.20	3.63	3.66	4.20	48.46
13NY	36.95	7.88	2.64	3.83	2.62	1.64	55.56
16NY	30.92	12.10	1.71	1.85	.98	2.02	49.58
17NY	16.40	3.20	1.26	1.12	2.21	1.14	25.33
20NY	69.44	5.37	.22	.21	.17	.19	75.60
25NY	22.62	14.84	2.40	2.45	3.20	5.42	50.93
26NY	27.61	7.25	.03	.06	.16	0.00	35.11
28NY	61.50	6.99	.39	.48	.45	1.69	71.50
29NY	31.00	12.07	.94	.90	.83	2.38	48.12
30NY	57.91	7.05	.39	.33	.33	.57	66.58
31NY	57.84	6.58	.99	1.45	3.65	1.02	71.53
32NY	18.84	13.91	1.87	2.19	1.64	2.03	40.48
33NY	36.81	17.17	2.97	2.81	3.98	.27	64.01
35NY	26.15	18.88	3.32	3.75	3.15	3.26	58.51
38NY	51.79	8.33	1.19	1.60	2.22	1.56	66.69
39NY	23.14	4.37	3.56	2.77	.05	0.00	33.89
44NY	13.11	0.00	21.93	4.21	2.13	.51	41.89
45NY	35.60	13.40	1.01	1.51	1.30	1.46	54.28
48NY	32.48	10.95	2.90	3.74	1.01	4.23	55.31
49NY	27.70	5.49	3.90	7.73	1.59	2.23	48.64
50NY	48.63	8.42	.88	.84	.85	3.01	62.63
51NY	31.27	17.97	2.03	2.13	1.72	4.46	59.58
52NY	16.51	9.32	1.46	2.19	8.66	0.00	38.14
59NY	49.80	5.30	4.67	.98	1.54	5.20	67.49
61NY	17.21	11.52	.59	.71	1.82	1.15	33.00
64NY	39.04	12.75	3.18	2.48	.97	2.00	60.42
02LA	17.70	9.88	3.64	3.74	4.28	12.47	51.71
03LA	10.52	5.65	1.92	29.77	1.50	.11	49.47
04LA	13.19	5.77	5.17	19.06	4.10	3.00	50.29
05LA	9.13	14.38	4.38	5.37	4.69	19.95	57.90
07LA	47.96	14.55	2.71	3.09	1.28	1.81	71.40
10LA	16.57	26.10	5.40	6.68	5.70	1.15	61.60
12LA	11.38	5.37	2.71	3.18	1.93	1.40	25.97
13LA	56.25	23.18	1.00	2.31	2.23	1.12	86.09
14LA	8.69	8.26	3.13	3.93	4.05	20.40	48.46
17LA	9.65	8.87	1.99	2.17	2.13	31.31	56.12
19LA	1.93	9.15	7.21	6.97	8.90	11.60	45.20
21LA	8.56	27.35	3.42	5.75	8.62	8.66	62.36
24LA	12.33	8.93	2.44	4.02	7.55	14.18	49.45

TABLE D-1. (cont'd) PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 61 TRUCKS FROM THE CAPE-21 STUDY

(ALL TRUCKS FROM NEW YORK AND LOS ANGELES)

TRUCK	9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES						Total
	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	
25LA	9.88	9.66	2.05	5.22	19.17	.88	46.86
26LA	16.26	12.50	5.99	6.23	6.84	7.73	55.55
28LA	10.73	14.80	4.30	6.61	7.79	8.40	52.63
30LA	17.28	22.94	4.81	4.74	3.25	4.37	57.39
32LA	11.72	13.31	3.62	4.19	3.32	4.35	40.51
35LA	23.98	6.80	4.08	3.46	3.42	3.26	45.00
36LA	10.93	15.55	6.93	7.25	3.07	6.69	50.42
39LA	10.72	5.17	3.53	5.09	3.73	25.43	53.67
40LA	6.20	10.25	3.41	4.98	12.67	13.74	51.25
42LA	8.81	9.44	5.34	9.89	9.69	1.62	44.79
43LA	2.95	8.22	4.25	6.94	5.73	30.61	58.70
47LA	9.75	16.22	3.72	4.62	5.23	25.86	65.40
98LA	8.34	20.37	3.12	4.17	6.29	18.16	60.45
AVG.	24.96	11.03	3.15	4.22	3.59	6.20	53.14
MAX.	69.44	27.35	21.93	29.77	19.17	31.31	
MIN.	1.93	0.00	0.00	.06	.05	0.00	
RANG	67.51	27.35	21.93	29.71	19.12	31.31	
S.D.	16.59	5.85	2.97	4.48	3.32	7.67	11.75
Coef. of Var.%	66.5	53.0	94.3	106.2	92.5	123.7	22.1

TABLE D-2. PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 52 TRUCKS FROM THE CAPE-21 STUDY

(SINGLE UNIT TRUCKS FROM NEW YORK AND LOS ANGELES)

	9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES						
TRUCK	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
02NY	40.54	0.00	0.00	10.19	1.82	4.32	56.87
03NY	34.47	12.04	1.94	2.81	2.40	3.57	57.23
04NY	23.48	18.64	1.36	1.29	.90	2.62	48.24
05NY	22.11	15.66	3.60	3.08	2.24	9.43	56.12
06NY	52.42	3.50	1.74	1.66	1.94	5.04	66.30
08NY	15.38	13.71	3.35	3.71	3.37	5.69	45.21
09NY	23.87	13.38	2.38	2.40	2.82	2.68	47.53
11NY	19.89	6.04	5.84	4.60	3.57	4.70	44.64
12NY	25.55	9.22	2.20	3.63	3.66	4.20	48.46
13NY	46.95	7.88	2.64	3.83	2.62	1.64	55.56
16NY	30.92	12.10	1.71	1.85	.98	2.02	49.58
17NY	16.40	4.20	1.26	1.12	2.21	1.14	25.33
20NY	69.49	5.17	.22	.21	.17	.19	75.60
25NY	22.62	14.84	2.40	2.45	3.20	5.42	50.93
26NY	27.61	7.25	.03	.06	.16	0.00	35.11
28NY	61.50	6.99	.39	.48	.95	1.69	71.50
29NY	31.00	12.07	.94	.90	.83	2.38	48.12
31NY	57.84	6.58	.99	1.45	3.65	1.02	71.53
32NY	18.84	13.91	1.87	2.19	1.64	2.03	40.48
33NY	36.81	17.17	2.97	2.81	3.98	.27	64.01
35NY	26.15	18.88	3.32	3.75	3.15	3.26	58.51
38NY	51.79	8.33	1.19	1.60	2.22	1.56	66.69
44NY	13.11	0.00	21.93	4.21	2.13	.51	41.89
45NY	35.60	13.40	1.01	1.51	1.30	1.46	54.28
48NY	32.48	10.95	2.90	3.74	1.01	4.23	55.31
49NY	27.70	5.49	3.90	7.73	1.59	2.23	48.64
50NY	48.63	8.42	.88	.84	.85	3.01	62.63
51NY	31.27	17.97	2.03	2.13	1.72	4.46	59.58
52NY	16.51	9.32	1.46	2.19	8.66	0.00	38.14
59NY	44.80	5.40	4.67	.98	1.54	5.20	67.49
61NY	17.21	11.52	.54	.71	1.82	1.15	33.00
04LA	13.19	5.77	5.17	19.06	4.10	3.00	50.29
05LA	9.13	14.48	4.38	5.37	4.69	19.95	57.90
07LA	47.96	14.55	2.71	3.09	1.28	1.81	71.40
10LA	16.57	26.10	5.40	6.68	5.70	1.15	61.60
13LA	56.25	23.18	1.00	2.31	2.23	1.12	86.09
14LA	8.69	8.26	3.13	3.43	4.05	20.90	48.46
17LA	9.65	8.87	1.99	2.17	2.13	31.31	56.12
19LA	1.93	9.15	7.21	6.97	8.40	11.60	45.20
21LA	8.56	27.35	3.42	5.75	8.62	8.66	62.36
24LA	12.33	8.94	2.44	4.02	7.55	14.18	49.45
25LA	9.88	9.66	2.05	5.22	19.17	.88	46.86
26LA	16.26	12.50	5.99	6.23	6.84	7.73	55.55
28LA	10.73	14.80	4.30	6.61	7.79	8.40	52.63
30LA	17.28	22.44	4.81	4.74	3.25	4.37	57.39
32LA	11.72	13.31	3.62	4.19	3.32	4.35	40.51
35LA	23.98	6.80	4.08	3.46	3.42	3.26	45.00
36LA	10.93	15.55	6.43	7.25	3.07	6.69	53.67

TABLE D-2. (cont'd) PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 52 TRUCKS FROM THE CAPE-21 STUDY

(SINGLE UNIT TRUCKS FROM NEW YORK AND LOS ANGELES)

	9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES						
TRUCK	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
40LA	6.20	10.25	3.41	4.98	12.67	13.74	51.25
42LA	8.81	9.44	5.34	9.89	9.69	1.62	44.79
47LA	9.75	16.22	3.72	4.62	5.23	25.86	65.40
48LA	8.34	20.37	3.12	4.17	6.29	18.16	60.45
AVG.	25.69	11.68	3.19	3.85	3.81	5.69	53.98
MAX.	69.44	27.45	21.93	19.06	19.17	31.31	86.09
MIN.	1.93	0.00	0.00	.06	.16	0.00	25.33
RANG	67.51	27.35	21.93	19.00	19.01	31.31	60.76
S.D.	16.53	6.02	3.18	3.17	3.47	6.79	11.38
Coef. of Var.%	64.3	51.5	99.7	82.3	91.1	119.3	21.1

TABLE D-3. PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 9 TRUCKS FROM THE CAPE-21 STUDY

(TRACTOR-TRAILERS FROM NEW YORK AND LOS ANGELES)

	9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES						
TRUCK	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
02NY	13.47	6.51	2.83	2.85	2.47	9.52	37.65
30NY	57.91	7.05	.39	.33	.33	.57	66.58
39NY	23.14	4.37	3.56	2.77	.05	0.00	33.89
64NY	39.04	12.75	3.18	2.48	.97	2.00	60.42
02LA	17.70	9.88	3.64	3.74	4.28	12.47	51.71
03LA	10.52	5.65	1.92	29.77	1.50	.11	49.47
12LA	11.38	5.37	2.71	3.18	1.93	1.40	25.97
39LA	10.72	5.17	3.53	5.09	3.73	25.43	53.67
43LA	2.95	8.22	4.25	6.94	5.73	30.61	58.70
AVG.	20.76	7.22	2.89	6.35	2.33	9.12	48.67
MAX.	57.91	12.75	4.25	29.77	5.73	30.61	66.58
MIN.	2.95	4.37	.39	.33	.05	0.00	25.97
RANG	54.96	8.38	3.86	29.44	5.68	30.61	40.61
S.D.	17.30	2.68	1.15	8.97	1.91	11.66	13.46
Coef. of Var.%	83.3	37.1	39.8	141.3	82.0	127.9	27.7

TABLE D-4. PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 35 TRUCKS FROM THE CAPE-21 STUDY

(ALL TRUCKS FROM NEW YORK)

		9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES					
TRUCK	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
02NY	40.54	0.00	0.00	10.19	1.82	4.32	56.87
03NY	34.97	12.04	1.94	2.81	2.90	3.57	57.23
04NY	23.38	18.69	1.36	1.29	.90	2.62	48.24
05NY	22.11	15.66	3.60	3.08	2.24	9.43	56.12
06NY	52.92	3.50	1.74	1.66	1.44	5.04	66.30
07NY	13.47	6.51	2.83	2.85	2.47	9.52	37.65
08NY	15.38	13.71	3.35	3.71	3.37	5.69	45.21
09NY	23.87	13.38	2.38	2.40	2.82	2.68	47.53
11NY	19.89	6.04	5.84	4.60	3.57	4.70	44.64
12NY	25.55	9.22	2.20	3.63	3.66	4.20	48.46
13NY	36.95	7.88	2.64	3.83	2.62	1.64	55.56
16NY	30.42	12.10	1.71	1.85	.98	2.02	49.58
17NY	16.40	3.20	1.26	1.12	2.21	1.14	25.33
20NY	69.44	5.37	.22	.21	.17	.19	75.60
25NY	22.62	14.84	2.40	2.45	3.20	5.42	50.93
26NY	27.61	7.25	.03	.06	.16	0.00	35.11
28NY	61.50	6.99	.39	.48	.45	1.69	71.50
29NY	31.00	12.07	.94	.90	.83	2.38	48.12
30NY	57.91	7.05	.39	.33	.33	.57	66.58
31NY	57.84	6.58	.99	1.45	3.65	1.02	71.53
32NY	18.84	13.91	1.87	2.19	1.64	2.03	40.48
33NY	36.81	17.17	2.97	2.81	3.98	.27	64.01
35NY	26.15	18.88	3.32	3.75	3.15	3.26	58.51
38NY	51.79	8.33	1.19	1.60	2.22	1.56	66.69
39NY	23.14	4.37	3.56	2.77	.05	0.00	33.89
44NY	13.11	0.00	21.93	4.21	2.13	.51	41.89
45NY	35.60	13.40	1.01	1.51	1.30	1.46	54.28
48NY	32.48	10.95	2.90	3.74	1.01	4.23	55.31
49NY	27.70	5.49	3.90	7.73	1.59	2.23	48.64
50NY	48.63	8.42	.88	.84	.85	3.01	62.63
51NY	31.27	17.97	2.03	2.13	1.72	4.46	59.58
52NY	16.51	9.32	1.46	2.19	8.66	0.00	38.14
59NY	49.80	5.30	4.67	.98	1.54	5.20	67.49
61NY	17.21	11.52	.59	.71	1.82	1.15	33.00
64NY	39.04	12.75	3.18	2.48	.97	2.00	60.42
AVG.	32.90	9.71	2.62	2.53	2.07	2.83	52.66
MAX.	69.44	18.88	21.93	10.19	8.66	9.52	75.60
MIN.	13.11	0.00	0.00	.06	.05	0.00	25.33
RANG	56.33	18.88	21.93	10.13	8.61	9.52	50.27
S.D.	15.04	5.02	3.63	2.03	1.59	2.38	12.37
Coeff. of Var. %	45.7	51.7	138.6	80.2	76.8	84.1	23.5

TABLE D-5. PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 31 TRUCKS FROM THE CAPE-21 STUDY

(SINGLE UNIT TRUCKS FROM NEW YORK)

TRUCK	9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES						
	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
02NY	40.54	0.00	0.00	10.19	1.82	4.32	56.87
03NY	34.47	12.04	1.94	2.81	2.40	3.57	57.23
04NY	23.38	18.69	1.36	1.29	.90	2.62	48.24
05NY	22.11	15.66	3.60	3.08	2.24	9.43	56.12
06NY	52.42	3.50	1.74	1.66	1.94	5.04	66.30
08NY	15.38	13.71	3.35	3.71	3.37	5.69	45.21
09NY	23.87	13.38	2.38	2.40	2.82	2.68	47.53
11NY	19.89	6.04	5.84	4.60	3.57	4.70	44.64
12NY	25.55	9.22	2.20	3.63	3.66	4.20	48.46
13NY	36.95	7.88	2.64	3.83	2.62	1.64	55.56
16NY	30.92	12.10	1.71	1.85	.98	2.02	49.58
17NY	16.40	3.20	1.26	1.12	2.21	1.14	25.33
20NY	69.44	5.37	.22	.21	.17	.19	75.60
25NY	22.62	14.84	2.40	2.45	3.20	5.42	50.93
26NY	27.61	7.25	.04	.06	.16	0.00	35.11
28NY	61.50	6.99	.39	.48	.45	1.69	71.50
29NY	31.00	12.07	.94	.90	.83	2.38	48.12
31NY	57.84	6.58	.99	1.45	3.65	1.02	71.53
32NY	18.84	13.91	1.87	2.19	1.64	2.03	40.48
33NY	36.91	17.17	2.97	2.81	3.98	.27	64.01
35NY	26.15	18.88	3.32	3.75	3.15	3.26	58.51
38NY	51.79	8.33	1.19	1.60	2.22	1.56	66.69
44NY	13.11	0.00	21.93	4.21	2.13	.51	41.89
45NY	35.60	13.40	1.01	1.51	1.30	1.46	54.28
48NY	32.48	10.95	2.90	3.74	1.01	4.23	55.31
49NY	27.70	5.49	3.90	7.73	1.59	2.23	48.64
50NY	48.63	8.42	.88	.84	.85	3.01	62.63
51NY	31.27	17.97	2.03	2.13	1.72	4.46	59.58
52NY	16.51	9.32	1.46	2.19	8.66	0.00	38.14
59NY	49.80	5.30	4.67	.98	1.54	5.20	67.49
61NY	17.21	11.52	.59	.71	1.82	1.15	33.00
AVG.	32.83	9.97	2.64	2.58	2.21	2.81	53.05
MAX.	69.44	18.88	21.93	10.19	8.66	9.43	75.60
MIN.	13.11	0.00	0.00	.06	.16	0.00	25.33
RANG	56.33	18.88	21.93	10.13	8.50	9.43	50.27
S.D.	14.76	5.16	3.83	2.13	1.60	2.11	12.06
Coef. of Var.%	45.0	51.8	145.1	82.6	72.4	75.1	22.7

TABLE D-6. PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 4 TRUCKS FROM THE CAPE-21 STUDY

(TRACTOR-TRAILERS FROM NEW YORK)

	9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES						
TRUCK	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
07NY	13.47	6.51	2.83	2.85	2.47	9.52	37.65
30NY	57.91	7.05	.39	.33	.33	.57	66.58
39NY	23.14	4.37	3.56	2.77	.05	0.00	33.89
64NY	39.04	12.75	3.18	2.48	.97	2.00	60.42
AVG.	33.39	7.67	2.49	2.11	.95	3.02	49.64
MAX.	57.91	12.75	3.56	2.85	2.47	9.52	66.58
MIN.	13.47	4.37	.39	.33	.05	0.00	33.89
RANG	44.44	8.38	3.17	2.52	2.42	9.52	32.69
S.D.	19.45	3.58	1.43	1.20	1.08	4.41	16.28
Coef. of Var. %	58.3	46.7	57.4	56.9	113.7	146.0	32.8

TABLE D-7. PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 26 TRUCKS FROM THE CAPE-21 STUDY

(ALL TRUCKS FROM LOS ANGELES)

	9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES						
TRUCK	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
02LA	17.70	9.88	3.64	3.74	4.28	12.47	51.71
03LA	10.52	5.65	1.92	29.77	1.50	.11	49.47
04LA	13.19	5.77	5.17	19.06	4.10	3.00	50.29
05LA	9.13	14.38	4.38	5.37	4.69	19.95	57.90
07LA	47.96	14.55	2.71	3.09	1.28	1.81	71.40
10LA	16.57	26.10	5.40	6.68	5.70	1.15	61.60
12LA	11.36	5.37	2.71	3.18	1.93	1.40	25.97
13LA	56.25	23.18	1.00	2.31	2.23	1.12	86.09
14LA	8.69	8.26	3.13	3.43	4.05	20.90	41.60
17LA	9.65	8.87	1.99	2.17	2.13	31.31	56.12
19LA	1.93	9.15	7.21	6.97	8.40	11.60	45.20
21LA	8.56	27.35	3.42	5.75	8.62	8.66	62.36
24LA	12.33	8.93	2.44	4.02	7.55	14.18	49.45
25LA	9.88	9.66	2.05	5.22	19.17	.88	46.86
26LA	16.26	12.50	5.99	6.23	6.84	7.73	55.55
28LA	10.73	14.80	4.30	6.61	7.79	8.40	52.63
30LA	17.28	22.94	4.81	4.74	3.25	4.37	57.39
32LA	11.72	13.31	3.62	4.19	3.32	4.35	40.51
35LA	23.98	6.80	4.08	3.46	3.42	3.26	45.00
36LA	10.93	15.55	6.93	7.25	3.07	6.69	50.42
39LA	10.72	5.17	3.53	5.09	3.73	25.43	53.67
40LA	6.20	10.25	3.41	4.98	12.67	13.74	51.25
42LA	8.81	9.44	5.34	9.89	9.69	1.62	44.79
43LA	2.95	8.22	4.25	6.94	5.73	30.61	58.70
47LA	9.75	16.22	3.72	4.62	5.23	25.86	65.40
48LA	8.34	20.37	3.12	4.17	6.29	18.16	60.45
AVG.	14.28	12.79	3.86	6.50	5.64	10.72	53.53
MAX.	56.25	27.35	7.21	29.77	19.17	31.31	86.09
MIN.	1.93	5.17	1.00	2.17	1.28	.11	25.09
RANG	54.32	22.18	6.21	27.60	17.89	31.20	61.00
S.D.	12.09	6.50	1.52	5.76	3.92	9.81	11.28
Coeff. of Var.%	84.6	50.8	39.4	88.6	69.5	91.5	21.1

TABLE D-8. PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 21 TRUCKS FROM THE CAPE-21 STUDY

(SINGLE UNIT TRUCKS FROM LOS ANGELES)

	9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES						
TRUCK	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
04LA	13.19	5.77	5.17	19.06	4.10	3.00	50.29
05LA	9.13	14.38	4.38	5.37	4.69	19.95	57.90
07LA	47.96	14.55	2.71	3.09	1.28	1.81	71.40
10LA	16.57	26.10	5.90	6.68	5.20	1.15	61.60
13LA	56.25	23.18	1.00	2.31	2.23	1.12	86.09
14LA	8.69	8.26	3.13	3.43	4.05	20.90	48.46
17LA	9.65	8.87	1.99	2.17	2.13	31.31	56.12
19LA	1.93	9.15	7.21	6.97	8.40	11.60	45.26
21LA	8.56	27.35	3.42	5.75	8.62	8.66	62.36
24LA	12.33	8.93	2.44	4.02	7.55	14.18	49.45
25LA	9.88	9.66	2.05	5.22	19.17	.88	46.86
26LA	16.26	12.50	5.99	6.23	6.84	7.73	55.55
28LA	10.73	14.80	4.30	6.61	7.79	8.40	52.63
30LA	17.28	22.94	4.81	4.74	3.25	4.37	57.39
32LA	11.72	13.31	3.62	4.19	3.32	4.35	40.51
35LA	23.98	6.80	4.08	3.46	3.42	3.26	45.00
36LA	10.93	15.55	6.43	7.25	3.57	6.69	50.42
40LA	6.20	10.25	3.41	4.98	12.67	13.74	51.25
42LA	8.81	9.44	5.34	9.89	9.69	1.62	44.79
47LA	9.75	16.22	3.72	4.62	5.23	25.86	65.40
48LA	8.34	20.37	3.12	4.17	6.29	18.16	60.45
AVG.	15.15	14.21	4.01	5.72	6.17	9.94	55.20
MAX.	56.25	27.35	7.21	19.06	19.17	31.31	86.09
MIN.	1.93	5.77	1.00	2.17	1.28	.88	40.51
RANG	54.32	21.58	6.21	16.89	17.89	30.43	45.58
S.D.	13.16	6.41	1.62	3.56	4.13	8.89	10.48
Coef. of Var.%	86.9	45.1	40.4	62.2	66.9	89.4	19.0

TABLE D-9. PERCENT TIME SPENT IN MODES OF THE NINE MODE GASOLINE HEAVY DUTY FTP FOR 5 TRUCKS FROM THE CAPE-21 STUDY

(TRACTOR-TRAILERS FROM LOS ANGELES)

	9 MODE GASOLINE HEAVY DUTY PROCEDURE MODES						
TRUCK	IDLE	CT	19 IN.	16 IN.	10 IN.	3 IN.	Total
02LA	17.70	9.88	3.64	3.74	4.28	12.47	51.71
03LA	10.52	5.65	1.92	29.77	1.50	.11	49.47
12LA	11.38	5.37	2.71	3.18	1.93	1.40	25.97
39LA	10.72	5.17	3.53	5.09	3.73	25.43	53.67
43LA	2.95	8.22	4.25	6.94	5.73	30.61	58.70
AVG.	10.65	6.86	3.21	9.74	3.43	14.00	47.90
MAX.	17.70	9.88	4.25	29.77	5.73	30.61	58.70
MIN.	2.95	5.17	1.92	3.18	1.50	.11	25.97
RANG	14.75	4.71	2.33	26.59	4.23	30.50	32.73
S.D.	5.23	2.09	.91	11.29	1.79	13.79	12.73
Coef. of Var.%	49.1	30.5	28.3	115.9	50.7	98.5	26.6

APPENDIX E

DATA IN SUPPORT OF DIESEL TRUCK WEIGHTING FACTOR ANALYSIS

TABLE E-1. PERCENT TIME SPENT IN MODES OF THE 13-MODE DIESEL HEAVY-DUTY FTP FOR 31 TRUCKS FROM THE CAPE-21 STUDY
(ALL TRUCKS FROM LOS ANGELES AND NEW YORK)

		13 MODE DIESEL HEAVY DUTY PROCEDURE MODES												
		INTERMEDIATE RPM POWER					RATED RPM POWER					MODAL		TOTAL/
TRUCK	IDLE	02 PCT	25 PCT	50 PCT	75 PCT	100PCT	02 PCT	25 PCT	50 PCT	75 PCT	100 PCT	TOTAL	MOTOR	NONMOTOR
06LA	16.26	.11	.36	.13	.17	.05	1.61	7.83	4.58	8.28	2.23	41.61	26.63	.5671
15LA	10.18	.00	.18	.05	.12	.10	3.93	12.59	5.12	6.16	.23	30.19	31.11	.5544
20LA	9.35	.59	8.09	2.55	2.73	.49	.20	2.40	1.72	3.06	2.77	29.75	19.63	.3485
22LA	19.33	.52	1.65	.53	.52	.24	.66	2.75	2.08	5.69	3.22	32.91	30.82	.4757
23LA	18.25	.57	1.47	.79	.00	.09	.75	4.40	2.59	4.33	.66	35.20	23.50	.4601
27LA	21.73	.37	1.50	.54	.62	.57	.42	2.22	1.06	2.06	4.20	35.37	37.27	.5638
29LA	16.41	.34	.42	.32	.41	.47	1.21	8.70	5.72	6.46	4.31	45.05	26.20	.6213
31LA	44.73	.16	1.75	.55	1.19	.04	.25	3.45	2.40	3.00	1.25	60.15	9.76	.6666
33LA	15.90	.00	1.25	.36	1.07	.16	.60	5.05	5.15	4.44	3.56	39.00	27.01	.5953
34LA	1.53	.23	2.19	1.33	2.76	1.23	.00	1.39	1.16	5.24	.30	17.52	9.76	.1941
37LA	5.51	.69	2.00	.79	.66	.71	.49	3.65	4.09	11.00	5.02	35.49	19.12	.4133
38LA	13.62	.20	1.71	.30	.06	2.20	.40	3.05	2.02	7.44	7.05	39.01	16.02	.4740
41LA	19.07	.73	3.16	1.09	1.37	0.00	1.32	7.61	1.97	2.79	.02	39.13	30.01	.5655
44LA	24.96	1.62	2.53	.73	.60	0.00	.00	7.66	3.37	6.19	.06	49.90	13.69	.5724
45LA	33.50	.24	.34	.15	.12	0.00	1.19	4.50	3.73	0.19	.22	52.39	25.65	.7040
46LA	19.70	.51	2.17	.56	1.65	0.00	.31	3.55	2.47	4.00	2.34	38.69	22.10	.4465
51LA	19.94	1.60	4.30	1.34	.94	.06	1.04	3.40	.44	1.03	.01	29.70	43.55	.5276
27NY	69.72	.49	1.30	.66	1.06	.49	.17	.60	.36	1.04	1.74	72.71	5.77	.7716
34NY	21.51	.06	.64	.34	1.16	.96	0.00	0.00	0.00	0.00	0.00	24.66	16.10	.2434
36NY	83.32	0.00	.35	.16	.41	.36	.01	.31	.15	.42	.27	85.75	3.57	.8842
37NY	21.47	.69	1.71	1.11	10.27	1.92	.02	.40	.33	2.05	1.61	42.96	2.19	.4340
42NY	29.04	.45	.03	0.00	0.00	0.00	5.19	.12	0.00	0.00	0.00	36.13	40.24	.6480
43NY	24.20	.56	2.76	1.00	1.03	.44	.41	4.04	2.57	5.44	1.36	49.02	19.32	.6076
53NY	47.25	.44	3.09	1.35	2.00	0.00	.00	.46	.36	1.00	1.02	57.13	10.65	.7023
54NY	49.07	.44	2.05	1.04	.45	.16	.10	1.04	1.01	1.56	.50	54.60	26.25	.7403
55NY	45.72	.23	.78	.35	1.41	0.00	.22	1.01	.47	4.51	0.00	55.20	31.62	.8073
56NY	49.10	.19	1.47	.65	2.43	1.20	0.00	0.00	0.00	0.00	0.00	55.12	15.37	.6513
57NY	42.47	2.16	3.41	1.50	3.16	.74	.00	.49	.24	.53	.16	55.47	7.74	.6012
60NY	37.12	.70	5.64	1.70	2.33	.20	0.00	.35	.17	.18	.07	48.54	11.44	.5481
62NY	56.74	.07	.66	.52	3.04	.01	0.00	.03	.04	.17	.02	61.40	12.33	.7004
65NY	12.26	1.07	2.20	1.67	2.34	.03	.18	1.17	2.35	6.40	15.43	45.15	5.47	.4776
AVG.	28.24	.57	2.05	.74	1.60	.42	.64	3.04	1.97	3.94	1.96	45.32	20.22	.5703
MAX.	83.32	2.16	8.09	2.55	10.27	2.20	5.19	12.59	5.72	11.00	15.43	85.75	40.24	.8848
MIN.	1.53	0.00	.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.52	2.19	.1941
RANG	81.79	2.16	8.06	2.55	10.27	2.20	5.19	12.59	5.72	11.00	15.43	68.23	46.10	.6941
S.D.	19.17	.50	1.79	.60	1.86	.57	1.04	3.10	1.79	3.10	3.00	14.09	11.57	.1490
C.V.	.68	.88	.83	.74	1.16	1.35	1.60	1.00	.91	.81	1.57	.31	.57	.2612

TABLE B-2. PERCENT TIME SPENT IN MODES OF THE THIRTEEN MODE DIESEL HEAVY DUTY FTP FOR 19 TRUCKS FROM THE CAPE-21 STUDY
(ALL TRACTOR TRAILERS FROM LOS ANGELES AND NEW YORK)

		13 MODE DIESEL HEAVY DUTY PROCEDURE MODES												
		INTERMEDIATE RPM POWER					RATED RPM POWER							
TRUCK	IDLE	02 PCT	25 PCT	50 PCT	75 PCT	100PCT	02 PCT	25 PCT	50 PCT	75 PCT	100 PCT	MODAL TOTAL	MOTOR	TOTAL/ NONMOTOR
27NY	64.72	.44	1.38	.66	1.06	.44	.17	.60	.36	1.09	1.79	72.71	5.77	.7716
39NY	21.51	.06	.64	.39	1.16	.90	0.00	0.00	0.00	0.00	0.00	24.66	16.10	.2939
42NY	29.84	.95	.03	0.00	0.00	0.03	5.19	.12	0.00	0.00	0.00	36.13	48.29	.6987
53NY	47.25	.99	3.04	1.35	2.00	0.00	.08	.96	.36	1.00	1.02	57.13	18.65	.7023
55NY	45.72	.23	.78	.35	1.91	0.00	.22	1.01	.97	4.51	0.00	55.20	31.62	.8073
56NY	44.10	.19	1.97	.65	2.43	1.28	0.00	0.00	0.00	0.00	0.00	55.12	15.37	.6513
62NY	37.12	.70	5.64	1.70	2.33	.28	0.00	.35	.17	.18	.07	48.54	11.44	.5481
65NY	12.26	1.07	2.20	1.67	2.39	.03	.18	1.17	2.35	6.90	15.93	45.15	5.47	.4776
06LA	16.26	.11	.36	.13	.17	.05	1.61	7.03	4.50	8.28	2.23	41.61	26.63	.5671
15LA	10.10	.08	.18	.05	.12	.10	3.93	12.59	5.12	6.16	.23	38.19	31.11	.5544
20LA	4.35	.59	8.09	2.55	2.73	.49	.20	2.90	1.72	3.06	2.77	29.75	19.63	.3908
22LA	19.73	.52	1.65	.53	.52	.29	.66	2.75	2.00	5.69	3.22	32.91	30.82	.4757
27LA	21.73	.37	1.50	.59	.62	.57	.42	2.22	1.06	2.06	4.28	35.37	37.27	.5638
33LA	15.98	.80	1.25	.36	1.07	.16	.60	5.05	5.15	4.98	3.56	39.80	27.01	.5453
39LA	1.53	.23	2.19	1.33	2.76	1.23	.08	1.39	1.16	5.29	.38	17.52	9.76	.1941
41LA	19.07	.73	3.16	1.09	1.37	0.00	1.32	7.61	1.97	2.79	.02	39.13	30.81	.5655
45LA	33.58	.29	.39	.15	.12	0.00	1.19	4.50	3.73	8.19	.22	52.39	25.65	.7046
46LA	19.78	.51	2.17	.56	1.65	0.00	.31	3.55	2.97	9.00	2.39	38.64	22.18	.4965
51LA	19.99	1.60	4.30	1.39	.99	.06	1.04	3.90	.99	1.03	.01	29.78	43.55	.5275
AVG.	24.96	.53	2.13	.81	1.30	.31	.88	3.00	1.89	3.75	1.97	41.56	23.79	.5522
MAX.	64.72	1.60	8.09	2.55	2.76	1.28	5.19	12.59	5.15	9.00	15.93	72.71	48.29	.8073
MIN.	1.53	.06	.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.52	5.47	.1941
RANG	63.19	1.54	8.06	2.55	2.76	1.28	5.19	12.59	5.15	9.00	15.93	55.19	42.82	.6131
S.D.	17.03	.40	2.05	.69	.99	.42	1.39	3.33	1.77	3.19	3.56	13.07	12.15	.1567
C.V.	.68	.75	.96	.85	.68	1.35	1.58	1.11	.96	.85	1.80	.31	.51	.2837

TABLE B-3. PERCENT TIME SPENT IN MODES OF THE THIRTEEN MODE DIESEL HEAVY DUTY FTP FOR 12 TRUCKS FROM THE CAPE-21 STUDY
(ALL SINGLE UNIT TRUCKS FROM LOS ANGELES AND NEW YORK)

		13 MODE DIESEL HEAVY DUTY PROCEDURE MODES												
		INTERMEDIATE RPM POWER					RATED RPM POWER							
TRUCK	IDLE	02 PCT	25 PCT	50 PCT	75 PCT	100PCT	02 PCT	25 PCT	50 PCT	75 PCT	100 PCT	MODAL TOTAL	MOTOR	TOTAL/ NONMOTOR
23LA	10.26	.57	1.97	.79	.00	.09	.75	4.90	2.59	9.33	.66	35.20	23.50	.4601
24LA	16.91	.39	.92	.38	.41	.47	1.21	8.70	5.72	6.96	4.31	45.85	26.20	.6213
31LA	44.73	.16	1.75	.55	1.19	.09	.25	3.95	2.90	3.00	1.25	60.15	9.76	.6666
37LA	5.51	.69	2.00	.79	.66	.71	.49	3.65	4.09	11.00	6.02	35.99	19.12	.4133
38LA	13.62	.20	1.71	.30	.86	2.20	.90	3.05	2.02	7.44	7.05	39.01	16.02	.4740
44LA	24.96	1.62	2.53	.73	.60	0.00	.08	7.66	3.37	6.19	.86	44.90	13.69	.5724
36NY	83.32	0.00	.35	.16	.41	.35	.01	.31	.15	.42	.27	85.75	3.57	.8892
37NY	21.97	.69	1.71	1.11	10.27	1.92	.02	.90	.33	2.05	1.61	42.96	2.19	.4390
43NY	24.20	.56	2.76	1.08	1.03	.99	.41	4.09	2.57	5.99	1.36	49.02	19.32	.6076
54NY	44.07	.44	2.05	1.09	.95	.16	.10	1.09	1.01	1.56	.50	54.60	26.25	.7403
57NY	42.97	2.16	3.91	1.54	3.15	.79	.08	.44	.29	.53	.16	55.47	7.79	.6016
60NY	56.79	.07	.66	.58	3.09	.01	0.00	.03	.09	.17	.08	61.90	12.33	.7059
AVG.	32.44	.63	1.93	.75	1.95	.59	.38	3.22	2.10	4.23	1.93	51.26	14.55	.5980
MAX.	83.32	2.16	3.91	1.54	10.27	2.20	1.21	8.70	5.72	11.00	7.05	85.75	26.25	.8892
MIN.	5.51	0.00	.35	.16	.41	0.00	0.00	.03	.09	.17	.08	35.20	2.19	.4133
RANG	77.81	2.16	3.56	1.38	9.86	2.20	1.21	8.67	5.63	10.83	6.97	50.55	24.06	.4760
S.D.	21.09	.64	1.00	.39	2.78	.73	.39	2.89	1.64	3.39	2.07	13.96	8.13	.1394
C.V.	.65	1.01	.52	.53	1.43	1.23	1.02	.90	.77	.79	1.17	.27	.56	.2337

TABLE E-4. PERCENT TIME SPENT IN MODES OF THE THIRTEEN MODE DIESEL HEAVY DUTY FTP FOR 17 TRUCKS FROM THE CAPE-21 STUDY
(ALL LOS ANGELES TRUCKS)

13 MODE DIESEL HEAVY DUTY PROCEDURE MODES

		INTERMEDIATE RPM POWER					RATED RPM POWER					MODAL		TOTAL/
TRUCK	IDLE	02 PCT	25 PCT	50 PCT	75 PCT	100PCT	02 PCT	25 PCT	50 PCT	75 PCT	100 PCT	TOTAL	MOTOR	NONMOTOR
06LA	16.26	.11	.36	.13	.17	.05	1.61	7.83	4.50	8.28	2.23	41.61	26.63	.5671
15LA	10.10	.08	.10	.05	.12	.10	3.93	12.59	5.12	6.16	.23	38.19	31.11	.5599
24LA	4.35	.59	8.09	2.55	2.73	.99	.20	2.90	1.72	3.06	2.77	29.75	19.63	.3485
22LA	19.33	.52	1.65	.53	.52	.29	.66	2.75	2.80	5.69	3.22	32.91	30.82	.4757
23LA	10.25	.57	1.97	.79	.80	.09	.75	4.90	2.59	4.33	.66	35.20	23.50	.4601
27LA	21.73	.37	1.50	.59	.62	.57	.92	2.22	1.06	2.06	4.28	35.37	37.27	.5638
29LA	16.91	.39	.92	.32	.91	.47	1.21	8.78	5.72	6.96	4.31	45.85	26.20	.6213
31LA	44.73	.16	1.75	.55	1.19	.09	.25	3.95	2.90	3.88	1.25	60.15	9.76	.6666
33LA	15.98	.08	1.25	.36	1.07	.16	.60	5.05	5.15	4.99	3.56	39.80	27.01	.5953
34LA	1.53	.23	2.19	1.33	2.76	1.23	.08	1.39	1.16	5.29	.38	17.52	9.76	.1991
37LA	5.51	.69	2.00	.79	.66	.71	.99	3.65	4.89	11.00	5.02	35.99	19.12	.4133
38LA	13.62	.28	1.71	.38	.86	2.20	.90	3.05	2.82	7.99	7.05	39.81	16.02	.4790
41LA	19.07	.73	3.16	1.09	1.37	0.00	1.32	7.61	1.97	2.79	.02	39.13	30.81	.5655
44LA	29.96	1.62	2.53	.73	.60	0.00	.88	7.66	3.37	6.19	.86	49.90	13.69	.5729
45LA	33.50	.29	.39	.15	.12	0.00	1.19	4.50	3.73	8.19	.22	52.39	25.65	.7090
46LA	19.70	.51	2.17	.56	1.65	0.00	.31	3.55	2.97	9.80	2.39	38.69	22.18	.4965
51LA	19.94	1.60	4.30	1.39	.99	.06	1.09	3.98	.99	1.03	.01	29.78	43.55	.5275
AVG.	17.07	.56	2.13	.72	1.03	.38	.87	4.99	3.12	5.76	2.26	38.08	23.69	.5147
MAX.	44.73	1.62	8.09	2.55	2.76	2.20	3.93	12.59	5.72	11.00	7.05	60.15	43.55	.7090
MIN.	1.53	.08	.10	.05	.12	0.00	.08	1.39	.99	1.03	.01	17.52	9.76	.1991
RANG	43.20	1.54	7.99	2.50	2.64	2.20	3.85	11.20	4.73	9.97	7.04	42.63	33.79	.5098
S.D.	10.44	.46	1.85	.61	.82	.58	.79	2.93	1.53	2.69	2.08	9.60	9.69	.1202
C.V.	.61	.81	.87	.85	.80	1.53	.91	.59	.49	.47	.92	.25	.41	.2335

TABLE B-5. PERCENT TIME SPENT IN MODES OF THE THIRTEEN MODE DIESEL HEAVY DUTY FTP FOR 11 TRUCKS FROM THE CAPE-21 STUDY
(LOS ANGELES TRACTOR TRAILERS)

		13 MODE DIESEL HEAVY DUTY PROCEDURE MODES												
		INTERMEDIATE RPM POWER					RATED RPM POWER							
TRUCK	IDLE	02 PCT	25 PCT	50 PCT	75 PCT	100PCT	02 PCT	25 PCT	50 PCT	75 PCT	100 PCT	MODAL TOTAL	MOTOR	TOTAL/ NONMOTOR
06LA	16.26	.11	.36	.13	.17	.05	1.61	7.03	4.58	8.20	2.23	41.61	26.63	.5671
15LA	10.18	.08	.18	.05	.12	.10	3.93	12.54	5.12	6.16	.23	38.19	31.11	.5544
20LA	9.35	.59	8.09	2.55	2.73	.99	.20	2.90	1.72	3.06	2.77	29.75	19.63	.3405
22LA	14.33	.52	1.65	.53	.52	.29	.66	2.75	2.00	5.69	3.22	32.91	30.02	.4757
27LA	21.73	.37	1.50	.59	.62	.57	.92	2.22	1.06	2.06	4.28	35.37	37.27	.5630
33LA	15.98	.08	1.25	.36	1.07	.16	.60	5.05	5.15	4.99	3.56	39.00	27.01	.5953
39LA	1.53	.23	2.19	1.33	2.76	1.23	.00	1.34	1.16	5.29	.30	17.52	9.76	.1991
41LA	14.07	.73	3.16	1.09	1.37	0.00	1.32	7.61	1.97	2.79	.02	39.13	30.01	.5655
45LA	33.58	.29	.39	.15	.12	0.00	1.19	4.58	3.73	0.19	.22	52.39	25.65	.7090
46LA	14.70	.51	2.17	.56	1.65	0.00	.31	3.55	2.97	9.80	2.39	30.69	22.10	.4965
51LA	14.94	1.60	4.30	1.39	.99	.06	1.09	3.90	.99	1.03	.01	29.70	43.55	.5275
AVG.	15.16	.53	2.29	.78	1.17	.26	.49	4.05	2.89	5.20	1.75	35.91	27.22	.5039
MAX.	33.58	1.60	8.09	2.55	2.76	1.23	3.93	12.54	5.15	9.80	4.28	52.39	43.55	.7090
MIN.	1.53	.08	.18	.05	.12	0.00	.00	1.34	.99	1.03	.01	17.52	9.76	.1991
RANG	32.05	1.52	7.91	2.50	2.64	1.23	3.93	11.20	4.16	8.77	4.27	34.88	33.79	.5099
S.D.	8.53	.43	2.29	.74	.98	.38	.45	3.30	1.61	2.79	1.61	8.79	9.49	.1331
C.V.	.56	.82	1.00	.95	.84	1.43	.96	.80	.57	.58	.92	.24	.35	.2642

TABLE B-6. PERCENT TIME SPENT IN MODES OF THE THIRTEEN MODE DIESEL HEAVY DUTY FTP FOR 6 TRUCKS FROM THE CAPE-21 STUDY
(LOS ANGELES SINGLE UNIT TRUCKS)

		13 MODE DIESEL HEAVY DUTY PROCEDURE MODES												
		INTERMEDIATE RPM POWER					RATED RPM POWER							
TRUCK	IDLE	02 PCT	25 PCT	50 PCT	75 PCT	100PCT	02 PCT	25 PCT	50 PCT	75 PCT	100 PCT	MODAL TOTAL	MOTOR	TOTAL/ NONMOTOR
23LA	18.25	.57	1.97	.79	.80	.09	.75	4.90	2.59	4.33	.66	35.20	23.50	.4601
29LA	16.41	.34	.92	.32	.41	.47	1.21	8.78	5.72	6.96	4.31	45.05	26.20	.6213
31LA	44.73	.16	1.75	.55	1.19	.04	.25	3.95	2.40	3.88	1.25	60.15	9.76	.6666
37LA	5.51	.69	2.08	.79	.66	.71	.44	3.65	4.89	11.00	5.02	35.49	14.12	.4133
38LA	13.62	.28	1.71	.38	.86	2.20	.40	3.05	2.82	7.44	7.05	39.01	16.02	.4790
44LA	24.96	1.62	2.53	.73	.60	0.00	.88	7.66	3.37	6.19	.86	44.90	13.69	.5729
AVG.	20.58	.61	1.83	.59	.75	.58	.66	5.33	3.63	6.63	3.19	44.30	17.21	.5396
MAX.	44.73	1.62	2.53	.79	1.19	2.20	1.21	8.78	5.72	11.00	7.05	60.15	26.20	.6666
MIN.	5.51	.16	.92	.32	.41	0.00	.25	3.05	2.40	3.88	.66	35.20	9.76	.4133
RANG	39.22	1.46	1.61	.47	.78	2.20	.96	5.73	3.32	7.12	6.39	24.95	16.44	.2533
S.D.	13.42	.53	.55	.21	.27	.84	.35	2.37	1.36	2.57	2.65	9.69	6.31	.1008
C.V.	.65	.87	.29	.35	.35	1.43	.53	.45	.38	.39	.83	.22	.37	.1876

TABLE E-7. PERCENT TIME SPENT IN MODES OF THE THIRTEEN MODE DIESEL HEAVY DUTY FTP FOR 14 TRUCKS FROM THE CAPE-21 STUDY
(ALL NEW YORK TRUCKS)

		13 MODE DIESEL HEAVY DUTY PROCEDURE MODES												
		INTERMEDIATE RPM POWER					RATED RPM POWER					MODAL		TOTAL/
TRUCK	IDLE	02 PCT	25 PCT	50 PCT	75 PCT	100PCT	02 PCT	25 PCT	50 PCT	75 PCT	100 PCT	TOTAL	MOTOR	NONMOTOR
27NY	64.72	.49	1.38	.66	1.06	.49	.17	.60	.36	1.04	1.74	72.71	5.77	.7716
34NY	21.51	.06	.69	.34	1.16	.90	0.00	0.00	0.00	0.00	0.00	24.66	16.10	.2939
36NY	83.32	0.00	.35	.16	.41	.35	.01	.31	.15	.42	.27	85.75	3.57	.8892
37NY	21.97	.69	1.71	1.11	10.27	1.42	.02	.48	.33	2.05	1.61	42.96	2.19	.4390
42NY	29.04	.45	.03	0.00	0.00	0.00	5.19	.12	0.00	0.00	0.00	36.13	44.29	.6480
43NY	29.20	.56	2.76	1.00	1.03	.44	.41	4.04	2.57	5.99	1.36	49.02	19.32	.6076
53NY	47.25	.44	3.09	1.35	2.00	0.00	.00	.46	.36	1.00	1.02	57.13	18.65	.7023
54NY	49.07	.44	2.05	1.04	.95	.16	.10	1.04	1.01	1.56	.50	54.68	26.25	.7403
55NY	45.72	.23	.70	.35	1.91	0.00	.02	1.01	.47	4.51	0.00	55.20	31.62	.8073
56NY	49.10	.19	1.47	.65	2.43	1.20	0.00	0.00	0.00	0.00	0.00	55.12	15.37	.6513
57NY	42.97	2.16	3.41	1.54	3.15	.74	.00	.44	.24	.53	.16	55.47	7.74	.6012
60NY	37.12	.70	5.64	1.70	2.33	.20	0.00	.35	.17	.10	.07	48.54	11.44	.5481
62NY	56.74	.07	.66	.58	3.04	.01	0.00	.03	.04	.17	.02	61.40	12.33	.7004
65NY	12.26	1.07	2.20	1.67	2.34	.03	.10	1.17	2.35	6.40	15.43	45.15	5.47	.4776
AVG.	41.82	.57	1.96	.87	2.30	.47	.46	.70	.57	1.73	1.54	53.13	16.00	.6377
MAX.	83.32	2.16	5.64	1.70	10.27	1.42	5.19	4.04	2.57	6.40	15.43	85.75	44.29	.8892
MIN.	12.26	0.00	.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.66	2.19	.2939
RANG	71.06	2.16	5.61	1.70	10.27	1.42	5.19	4.04	2.57	6.40	15.43	61.09	42.10	.5953
S.D.	18.76	.56	1.57	.56	2.48	.57	1.37	1.07	.84	3.24	4.38	14.81	12.62	.1503
C.V.	.45	.98	.80	.64	1.08	1.21	2.96	1.57	1.46	1.87	2.84	.28	.79	.2403

TABLE D-8. PERCENT TIME SPENT IN MODES OF THE THIRTEEN MODE DIESEL HEAVY DUTY FTP FOR 8 TRUCKS FROM THE CAPE-21 STUDY
(NEW YORK TRACTOR TRAILERS)

		13 MODE DIESEL HEAVY DUTY PROCEDURE MODES												
		INTERMEDIATE RPM POWER					RATED RPM POWER							
TRUCK	IDLE	02 PCT	25 PCT	50 PCT	75 PCT	100PCT	02 PCT	25 PCT	50 PCT	75 PCT	100 PCT	MODAL TOTAL	MOTOR	TOTAL/ NONMOTOR
27NY	69.72	.99	1.30	.66	1.06	.99	.17	.60	.36	1.04	1.79	78.71	5.77	.7716
39NY	21.51	.06	.69	.39	1.16	.90	0.00	0.00	0.00	0.00	0.00	24.66	16.10	.2939
42NY	29.09	.95	.03	0.00	0.00	0.00	5.19	.12	0.00	0.00	0.00	36.13	48.29	.6900
53NY	47.25	.99	3.09	1.35	2.00	0.00	.08	.96	.36	1.00	1.02	57.13	18.65	.7023
55NY	45.72	.23	.70	.35	1.91	0.00	.22	1.01	.47	4.51	0.00	55.20	21.62	.8073
56NY	49.10	.19	1.97	.65	2.93	1.20	0.00	0.00	0.00	0.00	0.05	55.12	15.37	.6513
60NY	37.12	.70	5.69	1.70	2.33	.20	0.00	.35	.17	.10	.07	40.59	11.99	.5981
65NY	12.26	1.07	2.20	1.67	2.39	.03	.10	1.17	2.35	6.90	15.93	45.15	5.97	.4776
AVG.	38.99	.52	1.96	.85	1.66	.37	.73	.56	.46	1.65	2.28	49.33	19.00	.6100
MAX.	69.72	1.07	5.69	1.70	2.93	1.20	5.19	1.17	2.35	6.90	15.93	78.71	48.29	.8073
MIN.	12.26	.06	.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.66	5.97	.2939
RANG	57.46	1.01	5.66	1.70	2.93	1.20	5.19	1.17	2.35	6.90	15.93	54.05	42.32	.5134
S.D.	18.03	.36	1.70	.69	.86	.49	1.80	.49	.78	2.49	5.35	15.52	14.90	.1706
C.V.	.46	.71	.89	.76	.52	1.31	2.47	.86	1.69	1.48	2.35	.29	.78	.2797

TABLE B-9. PERCENT TIME SPENT IN MODES OF THE THIRTEEN MODE DIESEL HEAVY DUTY FTP FOR 6 TRUCKS FROM THE CAPE-21 STUDY
(NEW YORK SINGLE AXLE TRUCKS)

		13 MODE DIESEL HEAVY DUTY PROCEDURE MODES												
		INTERMEDIATE RPM POWER					RATED RPM POWER							
TRUCK	IDLE	02 PCT	25 PCT	50 PCT	75 PCT	100PCT	02 PCT	25 PCT	50 PCT	75 PCT	100 PCT	MODAL TOTAL	MOTOR	TOTAL/ NONMOTOR
36NY	83.32	0.00	.35	.16	.91	.35	.01	.31	.15	.92	.27	85.75	3.57	.8998
37NY	21.97	.69	1.71	1.11	10.27	1.92	.02	.98	.33	2.05	1.61	42.96	2.19	.4390
43NY	29.28	.56	2.76	1.08	1.03	.99	.41	4.09	2.57	5.49	1.36	49.02	19.32	.6076
54NY	44.07	.44	2.05	1.04	.95	.16	.10	1.09	1.01	1.56	.58	59.60	26.25	.7903
57NY	42.97	2.16	3.91	1.54	3.15	.79	.08	.49	.29	.53	.16	55.97	7.79	.6012
62NY	56.79	.07	.66	.58	3.09	.01	0.00	.03	.09	.17	.02	61.90	18.33	.7009
AVG.	46.32	.65	2.09	.91	3.15	.60	.10	1.20	.78	1.89	.67	59.20	12.91	.6730
MAX.	83.32	2.16	3.91	1.54	10.27	1.92	.41	4.09	2.57	5.49	1.61	85.75	26.25	.8998
MIN.	21.97	0.00	.35	.16	.91	.01	0.00	.03	.09	.17	.02	42.96	2.19	.4390
RANG	61.35	2.16	3.56	1.38	9.36	1.91	.41	4.06	2.53	5.32	1.59	42.79	24.06	.4608
S.D.	21.03	.79	1.30	.49	3.60	.69	.16	1.53	.97	2.05	.66	15.07	9.91	.1581
C.V.	.45	1.20	.62	.54	1.17	1.15	1.51	1.27	1.39	1.11	1.00	.26	.77	.2349

TABLE E-10. TEST WEIGHT AND 32 kph DRIVING CYCLE FUEL RATE FOR 11 DIESEL TRUCKS TESTED UNDER CONTRACT 68-02-2147

Truck No.	Test Weight, kg*			32 kph Driving Cycle Fuel Rate, g/min*		
	Empty	Half	Full	Empty	Half	Full
19	5,216	7,258	9,072	133.14	168.40	164.94
20	11,113	22,226	33,340	220.77	283.73	326.20
21	11,113	22,226	33,340	242.50	296.43	365.79
22	11,113	22,226	33,340	213.27	257.56	295.78
23	11,113	22,226	33,340	226.45	279.53	314.35
24	11,113	22,226	33,340	218.87	261.26	319.68
25	11,113	22,226	33,340	211.36	284.71	347.96
26	7,258	14,515	21,773	180.09	205.45	240.52
27	11,113	22,226	33,340	222.00	282.26	342.20
28	7,258	11,113	18,371	173.49	179.79	258.70
29	7,258	9,299	11,113	153.03	168.71	160.15

---

* Data from Appendix D of Final Report under Contract 68-02-2147, "Study of Emissions from Heavy-Duty Vehicles," EPA-460/3-76-012, dated May 1976.

APPENDIX F

WORKING CURVES FROM EPA ANALYSIS OF ETHYL TRUCK AND BUS STUDY

The figures contained in this appendix are working curves from an EPA analysis of the raw data from the "Survey of Truck and Bus Operating Modes in Several Cities," by Ethyl Corporation under Contract No. PH86-62-12. This analysis was done around 1971-72. It is presented here since some of the data was used for comparison purposes in the present project. The curves are presented here as made available by EPA with some touch-up for legibility.

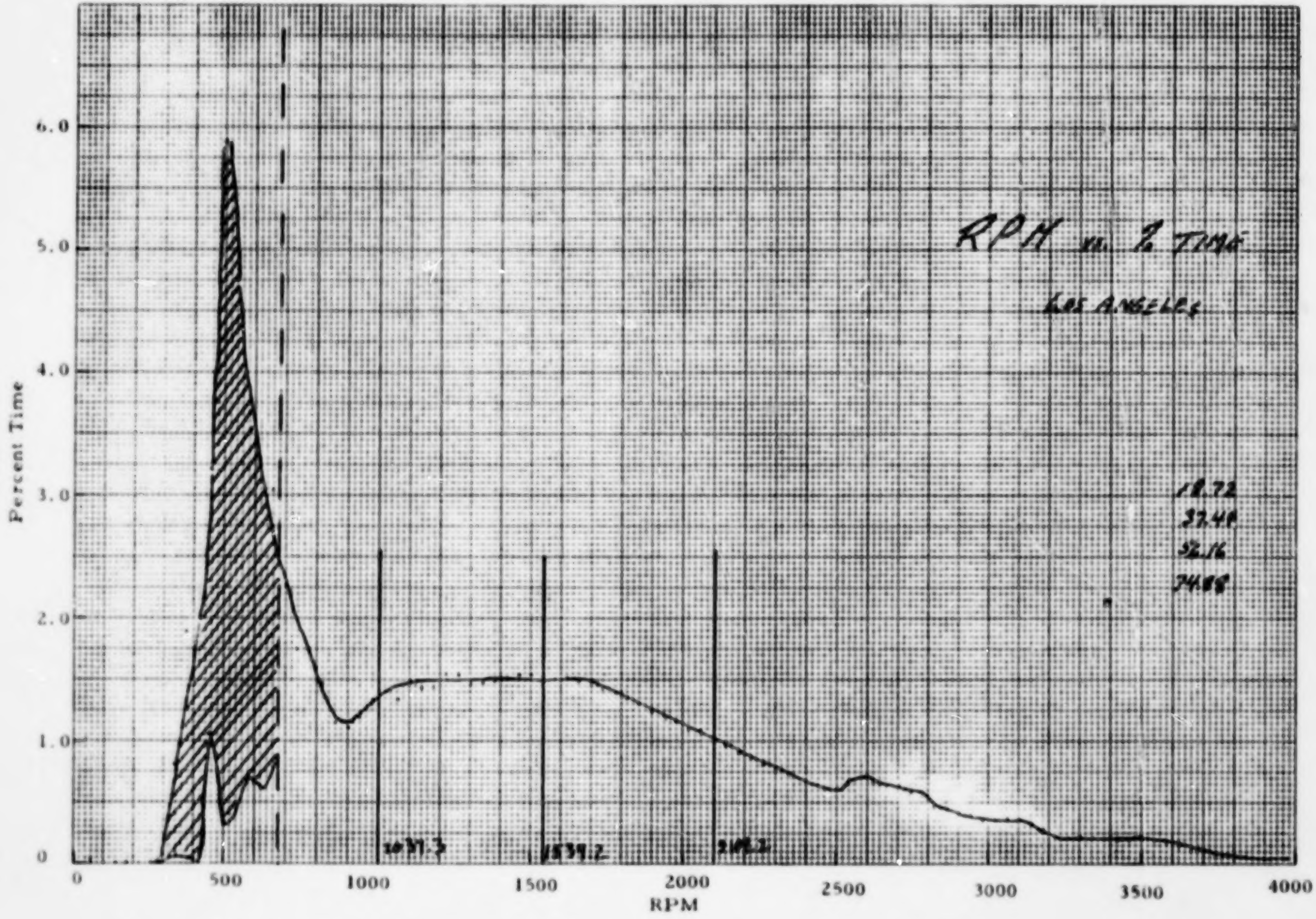


FIGURE F-1. RPM VERSUS PERCENT TIME FOR LOS ANGELES TRUCKS TESTED UNDER ETAB STUDY

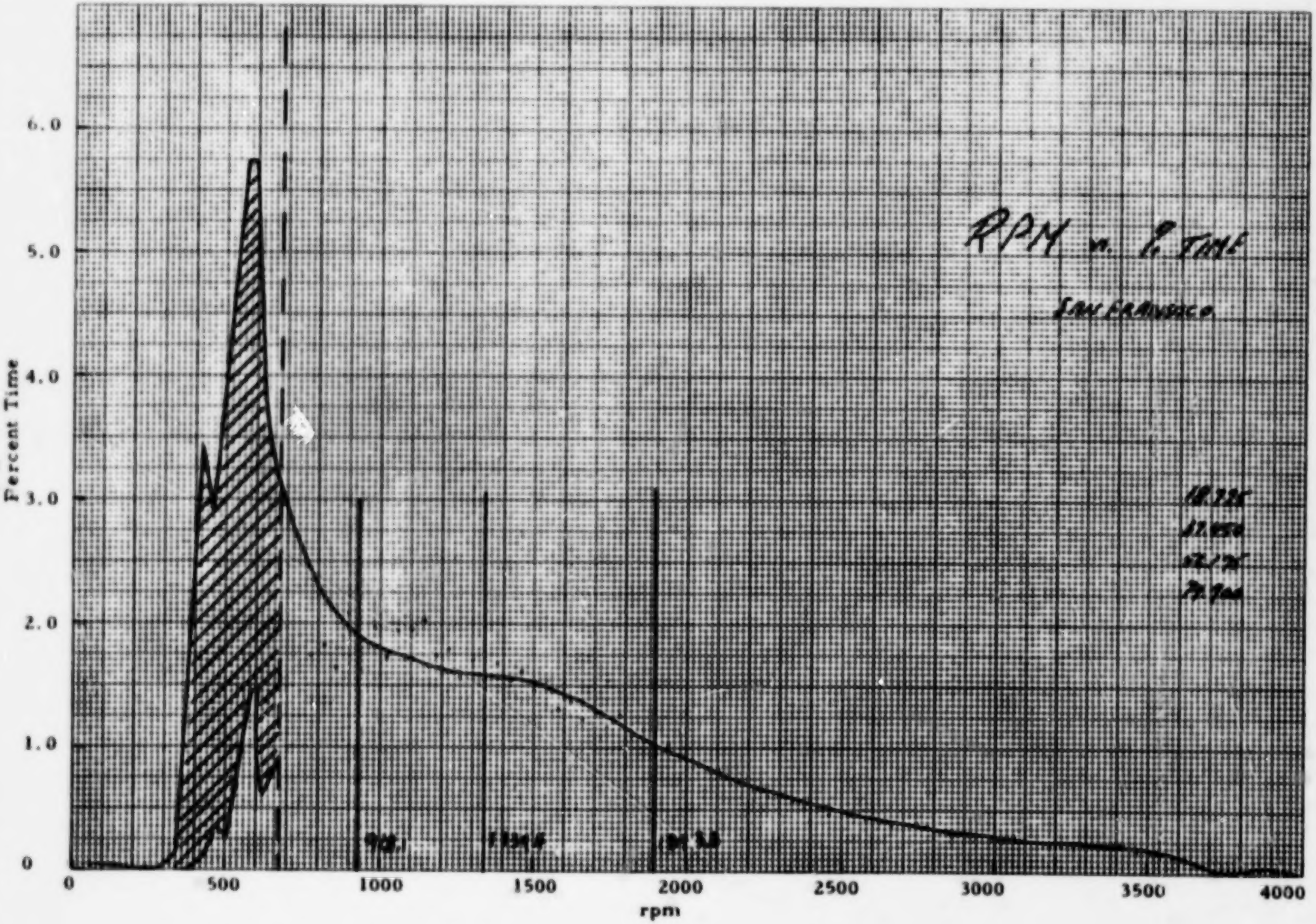


FIGURE F-2. RPM VERSUS TIME FOR SAN FRANCISCO TRUCKS TESTED UNDER ETAB STUDY

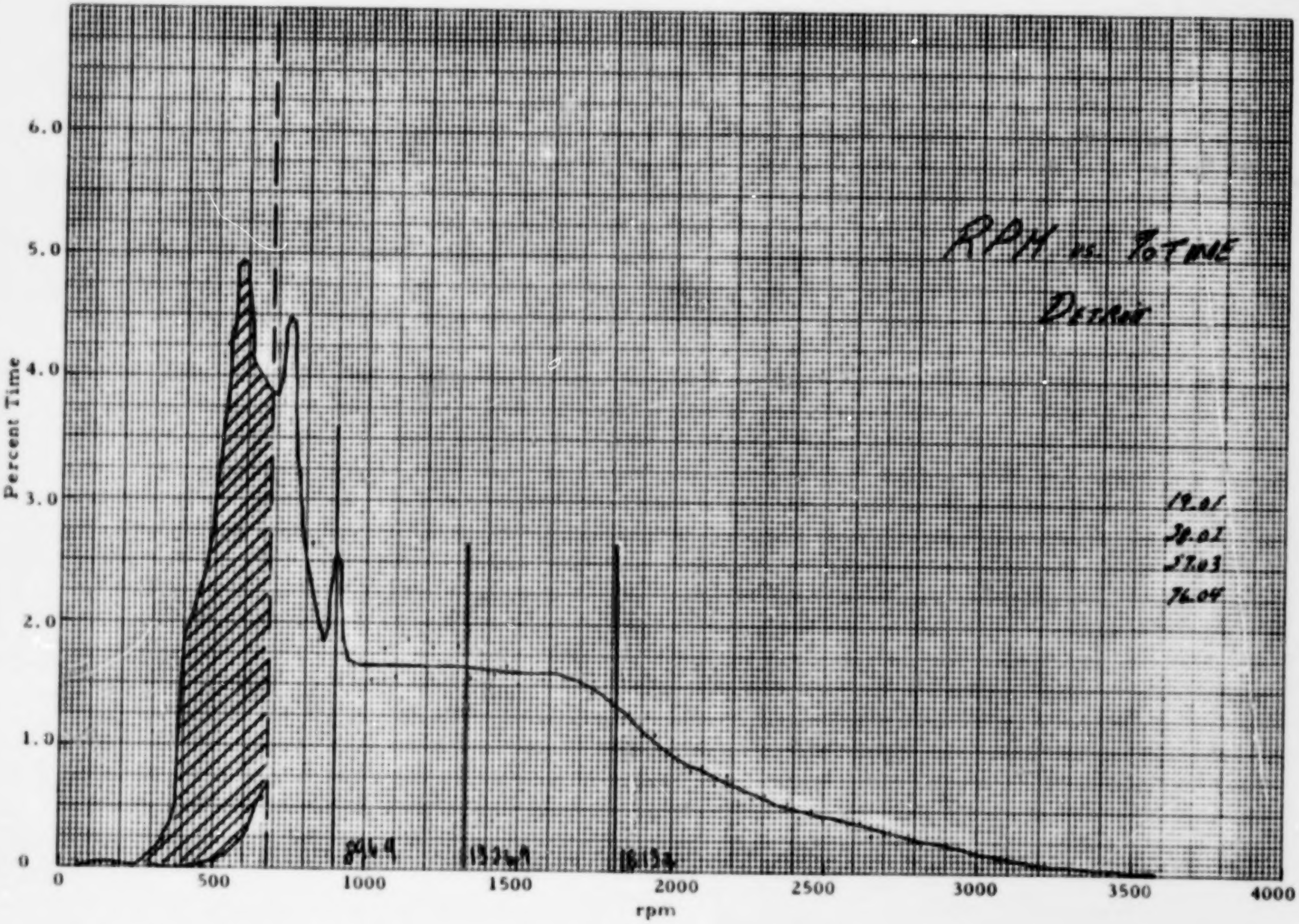


FIGURE F-3. RPM VERSUS PERCENT TIME FOR DETROIT TRUCKS TESTED UNDER ETAB STUDY

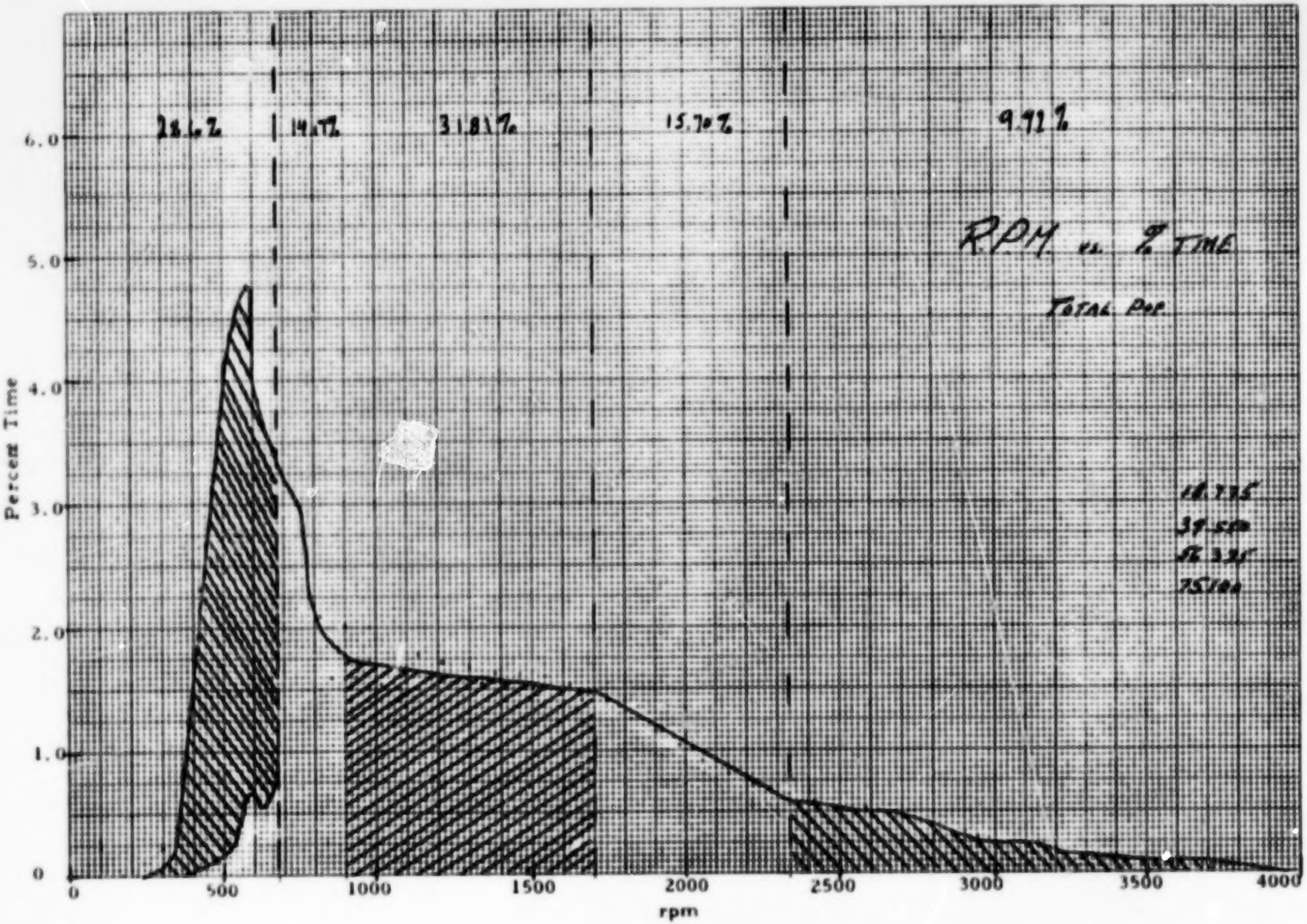


FIGURE F-4. RPM VERSUS PERCENT TIME FOR ALL TRUCKS TESTED UNDER ETAB STUDY

TABLE F-1. SOUTHWEST RESEARCH INSTITUTE INTERPRETATION OF PERCENT TIME IN VARIOUS RPM INTERVALS FROM FIGURE F-4.

RPM Interval	Percent Time Values at 50 RPM Intervals	Total Percent Time in RPM Interval
0-300	0, 0, 0, 0, 0.02	0.02
300-500	0.07, 0.39, 1.07, 2.32, 2.74	6.59
500-700	4.07, 4.52, 4.77, 3.85, 3.60	20.81
700-900	3.30, 3.05, 2.30, 2.08, 1.59	12.32
900-1100	2.01, 1.58, 1.72, 1.54, 1.68	8.53
1100-1300	1.62, 1.78, 1.60, 1.71, 1.57	8.28
1300-1500	1.68, 1.54, 1.62, 1.55, 1.62	8.01
1500-1700	1.52, 1.59, 1.49, 1.54, 1.41	7.55
1700-1900	1.46, 1.39, 1.39, 1.25, 1.25	8.13
1900-2100	1.15, 1.15, 1.02, 1.00, 0.91	5.23
2100-2300	0.89, 0.80, 0.81, 0.72, 0.70	3.92
2300-2500	0.64, 0.65, 0.59, 0.57, 0.52	2.97
2500-2700	0.54, 0.52, 0.51, 0.49, 0.48	2.54
2700-2900	0.44, 0.43, 0.42, 0.38, 0.33	2.00
2900-3100	0.32, 0.29, 0.27, 0.25, 0.25	1.38
3100-3300	0.24, 0.22, 0.19, 0.16, 0.15	0.96
3300-3500	0.15, 0.13, 0.12, 0.11, 0.10	0.61
3500-3700	0.10, 0.08, 0.06, 0.06, 0.04	0.34
3700-3900	0.04, 0.03, 0.03, 0.02, 0.02	0.14

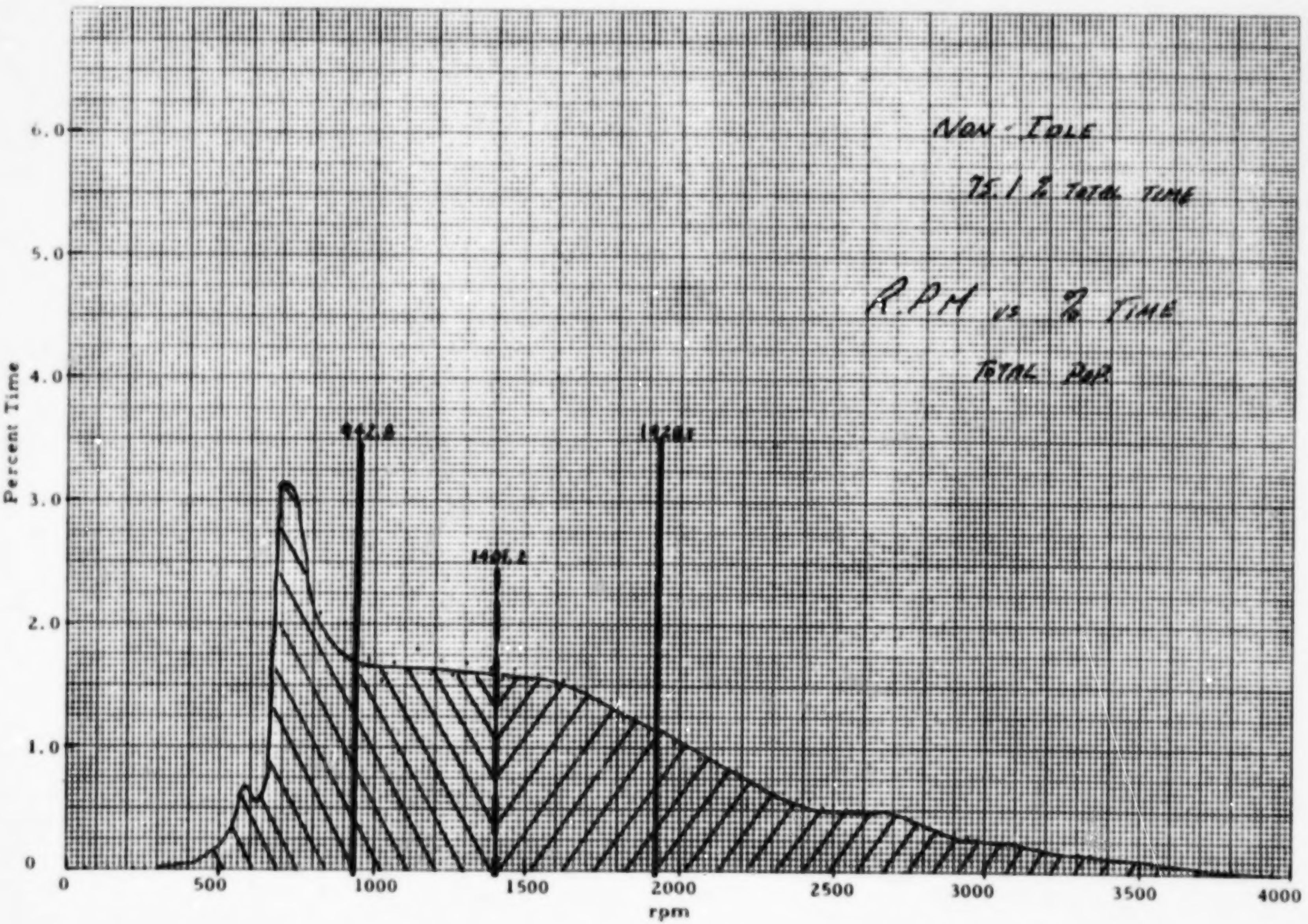


FIGURE F-5. RPM VERSUS PERCENT NON-IDLE TIME FOR ALL TRUCKS TESTED UNDER ETAB STUDY

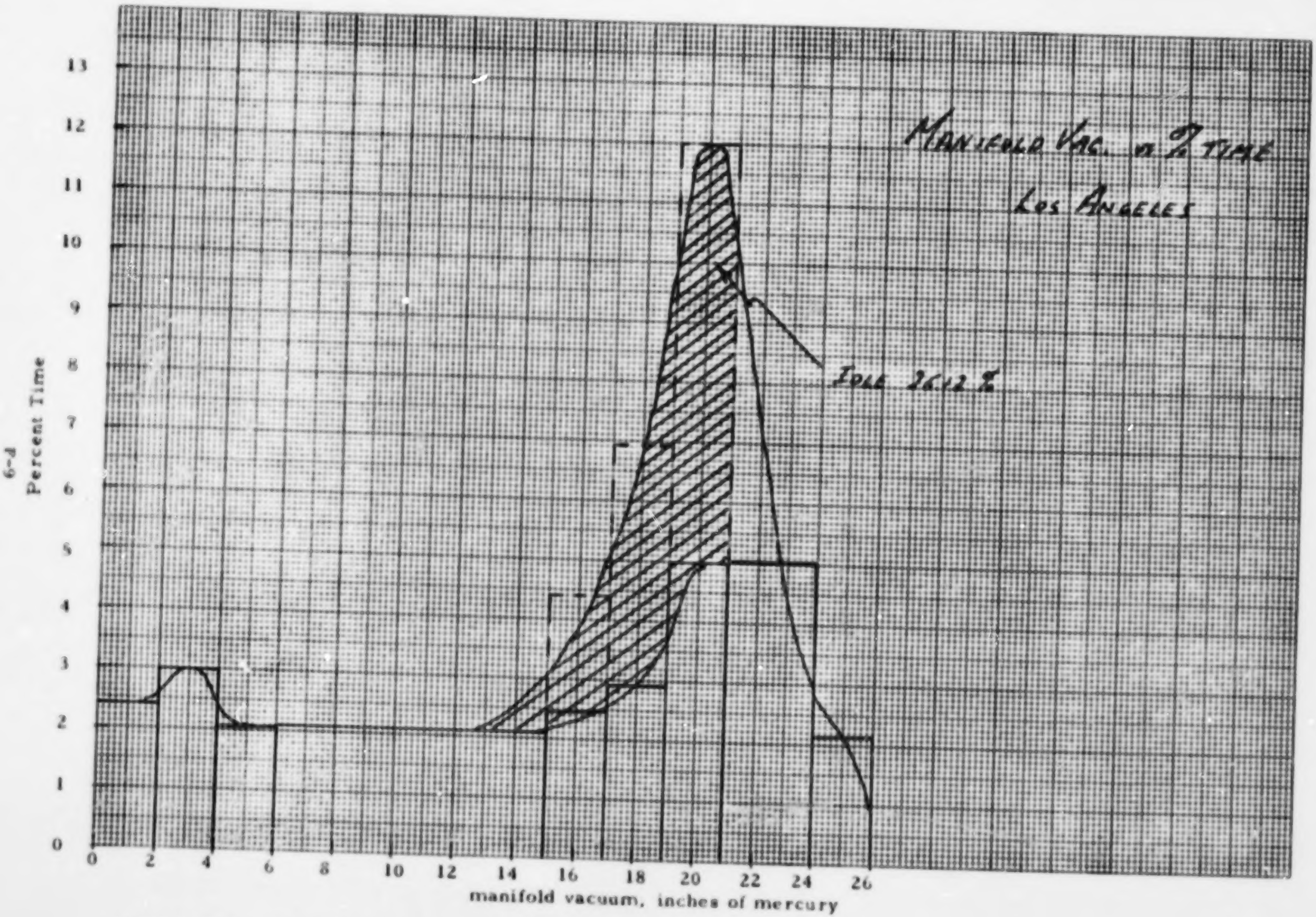


FIGURE F-6. MANIFOLD VACUUM VERSUS PERCENT TIME FOR LOS ANGELES TRUCKS, ETAB STUDY

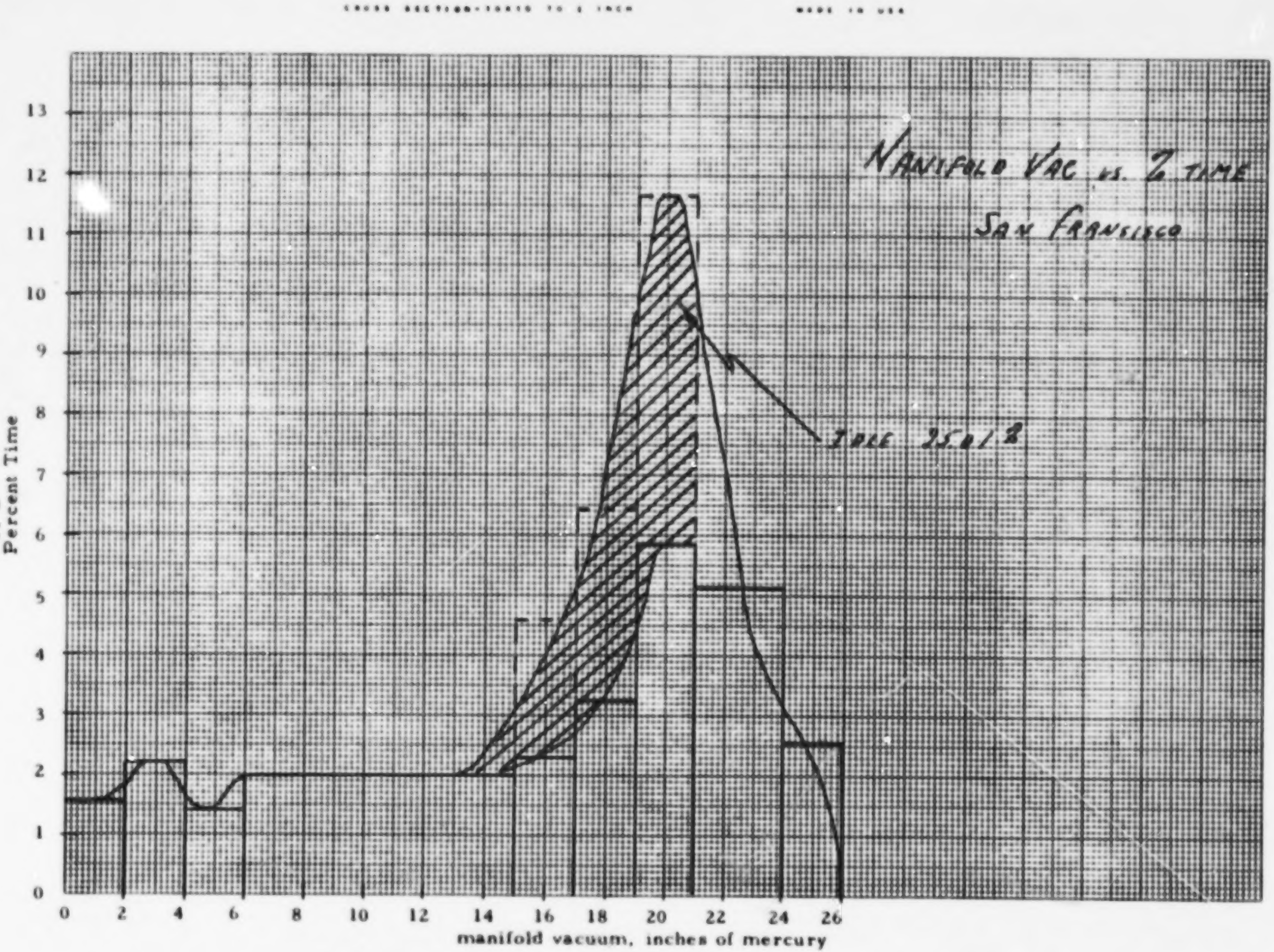


FIGURE F-7. MANIFOLD VACUUM VERSUS PERCENT TIME, SAN FRANCISCO TRUCKS, ETAB STUDY

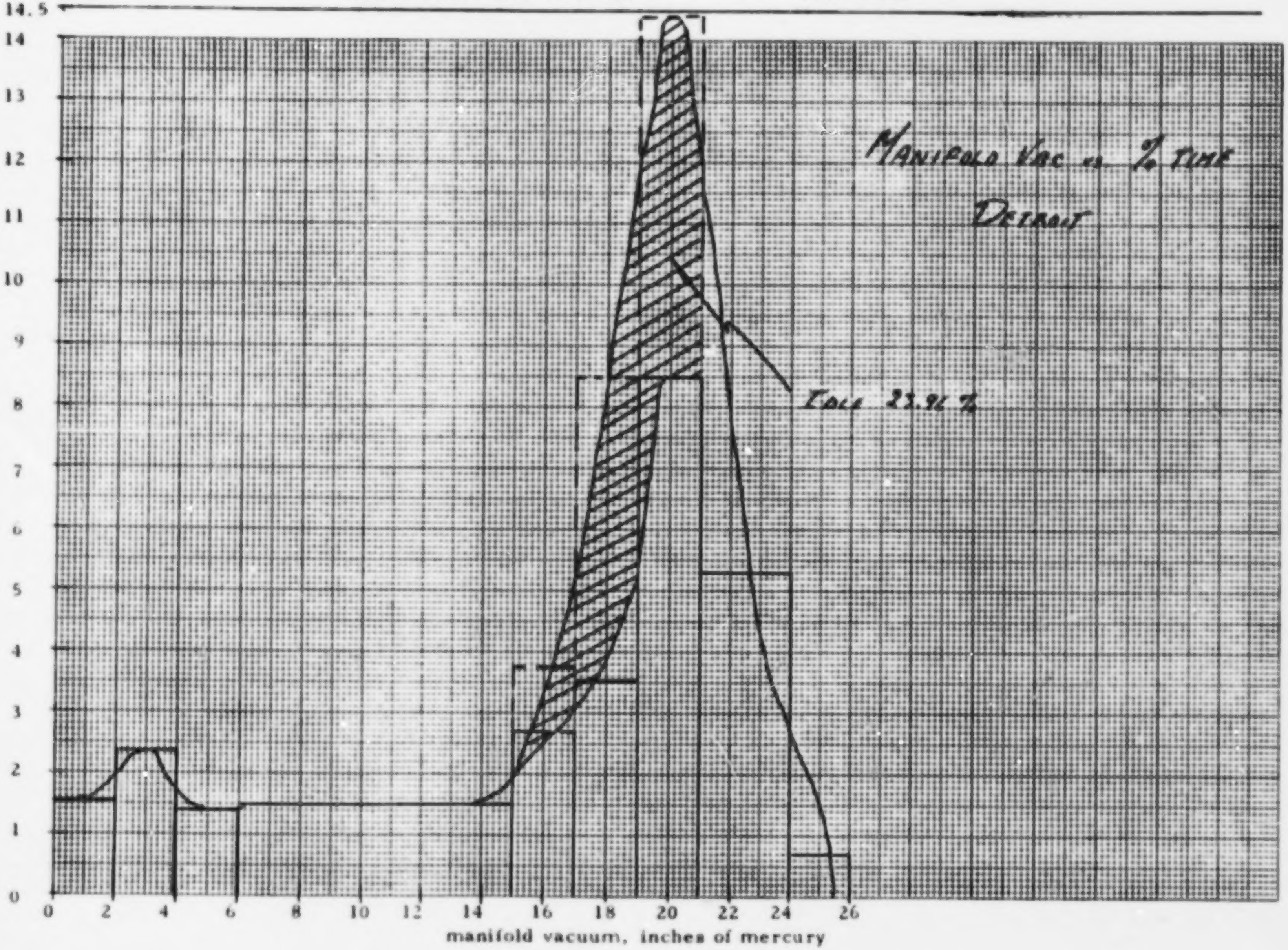


FIGURE F-8. MANIFOLD VACUUM VERSUS PERCENT TIME FOR DETROIT TRUCKS, ETAB STUDY

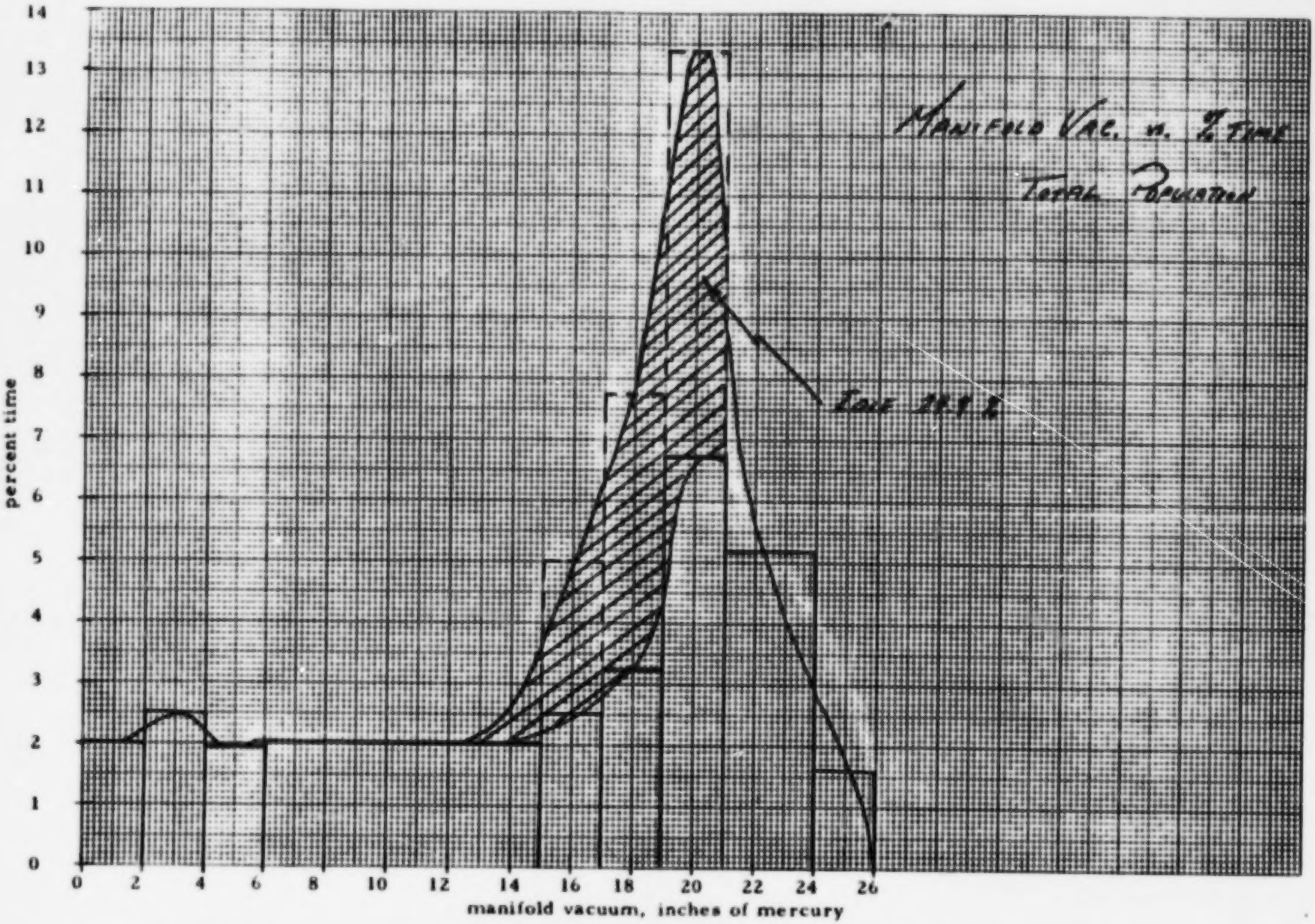


FIGURE F-9. MANIFOLD VACUUM VERSUS PERCENT TIME FOR ALL TRUCKS, ETAB STUDY